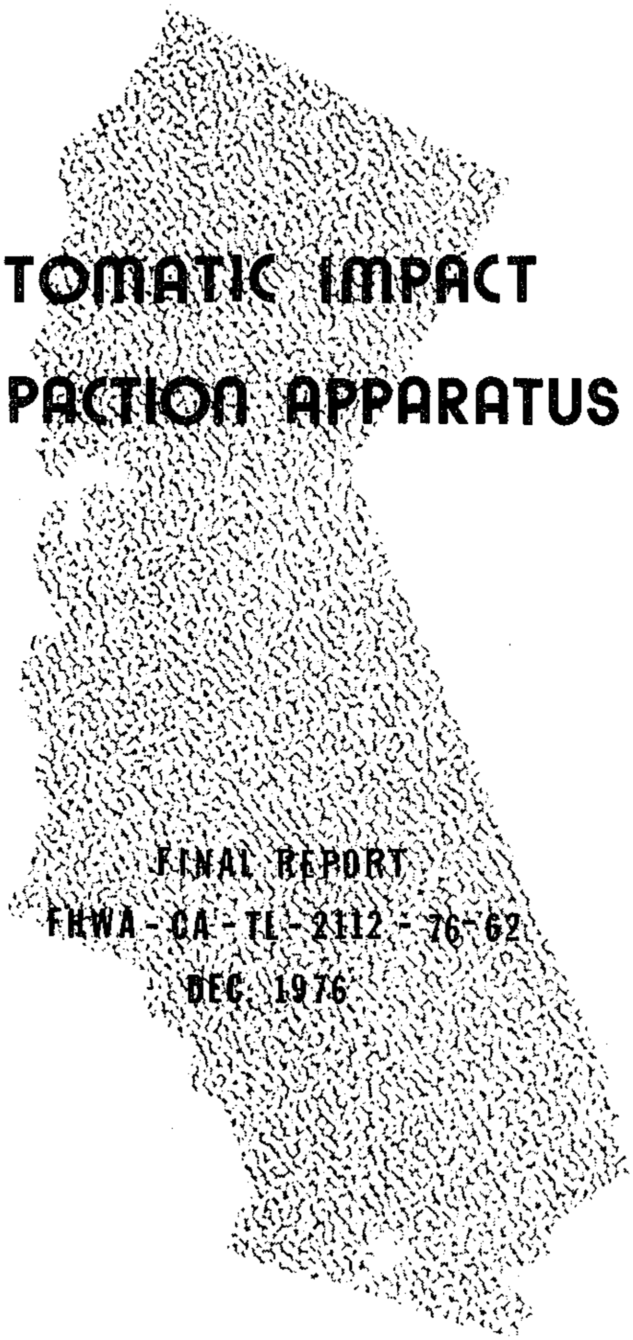
DIVISION OF STRUCTURES AND ENGINEERING SERVICES

TRANSPORTATION LABORATORY

RESEARCH REPORT



AUTOMATIC IMPACT COMPACTION APPARATUS

76-62

FINAL REPORT

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DEC. 1976

Prepared in Cooperation with the U.S. Department of Transportation,

Federal Highway Administration

Caltrans

CALIFORNIA DEPARTMENT OF TRANSPORTATION

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16. ABSTRACT

A laboratory evaluation of a mechanical impact soil compaction apparatus is reported. Comparisons of manual and mechanical procedures are made for test maximum soil density at optimum moisture content. Variations in test results between T.M. No. Calif. 216 and ASTM 1557-70 with the manual procedure and the mechanical compactor are discussed. Limits of variation between the mechanical compactor and the manual procedure are also presented. Compactor specifications and proposed methods for equipment calibration, operator certification, and laboratory determination of maximum wet density and relative compaction are given.

It was concluded that the use of the mechanical impact compactor in conjunction with the manual procedure is feasible.

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STATE OF CALIFORNIA
DEPARTMENT OF TRANSPORTATION
DIVISION OF STRUCTURES & ENGINEERING SERVICES
OFFICE OF TRANSPORTATION LABORATORY

TL No. 632112
Item No. F-4-25

Mr. C. E. Forbes
Chief Engineer

Dear Sir:

I have approved and now submit for your information this final research project report titled:

AUTOMATIC IMPACT COMPACTION APPARATUS

Study made by	Geotechnical Branch
Under the Supervision of	Raymond A. Forsyth, P. E.
Principal Investigators	Albin D. Hirsch, P. E. and Joseph B. Hannon, P. E.
Co-Investigator	Mas Hatano, P. E. and Bobby L. Lister
Report Prepared by	Mas Hatano, P. E. and Bobby L. Lister

Very truly yours,

George A Hill

GEORGE A. HILL
Chief, Office of Transportation Laboratory

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ACKNOWLEDGEMENTS

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The authors wish to express their thanks to the technicians that performed the testing and collected the data, in particular, Jan Shetler and Frank Champion. Appreciation is also extended to various personnel of the Office of Construction and the Roadbed and Concrete Branch of the Transportation Laboratory for their constructive comments concerning this report.

The contents of this report reflect the views of the Transportation Laboratory which is responsible for the facts and the accuracy of the data presented herein. The contents of this report do not necessarily reflect the official views or policies of the State of California or the Federal Highway Administration. This report does not constitute a standard, specification, or regulation.

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INTRODUCTION

In 1929, the California Division of Highways developed a test procedure for evaluating compaction of soils and aggregates. Basically, the method consisted of determining an inplace density and relating it to the laboratory test maximum density compacted according to a uniform procedure. This original concept is still universally used throughout the world in the quality control of earthwork construction.

An 1933, R. Proctor of the Bureau of Water Works and Supply of the City of Los Angeles, California, reported a similar compaction test procedure in the Engineering News Record.

Although the California and Proctor procedures were similar in concept, the apparatus and details of testing were somewhat different. The Proctor test gained widespread acceptance and led to other nationally recognized variations such as the AASHTO and ASTM methods.

California retained the original test developed in 1929 with very little change in apparatus or method of fabricating laboratory test specimens. In recent years, however, the advantages of adopting the more widely used AASHTO or ASTM tests from an administrative point of view have become increasingly apparent.

In 1957, Hveem(1) reported that the Calif. 216 and modified AASHTO T180 (equivalent to ASTM 1557) procedures on a given material produce equivalent test values. They yield nearly identical densities on certain soils and tend to alternate in high density on others. Eight soil samples were compared in this study. These, however, did not include materials that required a rock correction.

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In 1967, Sherman, Watkins and Prysock(2) reported that for practical purposes, the Calif. 216 and AASHTO T180 produced approximately equal average results. A total of 16 samples from two projects were compared but these also did not include any materials that required a rock correction.

It has been for many years unofficial department policy to utilize national standards and tests whenever possible. In those instances where national standards and tests are unsuitable or do not meet the needs of California, a California test or standard is developed for this purpose. An effort is usually made to modify the national standard or test along the lines which would make it acceptable in California or to have the California test adopted as a national standard.

In order to improve the test repeatability and increase production the AASHTO and ASTM procedures have included use of a mechanical compactor.

The purposes of this study were to determine the feasibility of adopting an automatic mechanical compactor as a supplemental compaction device and as a standard for certifying test operators; to determine the limits of variation between the mechanical and manual procedures; and to establish the advantages and disadvantages of changing from the present California Compaction Method (T.M. No. Calif. 216) to the ASTM 1557 procedure.

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OBJECTIVES

1. Evaluate use of a mechanical compactor for fabricating test specimens in determining maximum density.

2. Investigate procedures for calibrating manual and mechanical rammers.

3. Investigate the use of ASTM 1557-70 in lieu of the California method. Determine any differences in test results between the T. M. No. Calif. 216 and the ASTM 1557-70 using the manual procedure and the mechanical compactor.

4. Prepare a standard procedure for the State of California incorporating the better features of other test methods used for determining test maximum density which would conform more closely to a recognized national standard.

5. Determine limits of variation between use of mechanical compactor and manual procedure.

6. Develop a method to certify test operators by correlating the manual procedure to the mechanical procedure, using the mechanical procedure as the standard.

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CONCLUSIONS

1. The use of a mechanical rammer in conjunction with a manual rammer is feasible.

2. The calibration procedure for a manual or mechanical rammer as outlined in ASTM D2168 does not appear to be necessary when other items such as rammer weight and height of drop are checked.

3. The ASTM 1557 procedure when compared to the California procedure appears to give laboratory densities slightly lower for the sandy gravel and clay soils and slightly higher for the other soils tested in this study.

4. The test repeatability for the manual compaction procedure appeared to be slightly better than for the mechanical compaction procedure under closely controlled conditions. However, the difference did not appear to be significant.

5. The allowable variation between the ASTM 1557 manual and mechanical procedure when certifying test operators should not exceed 2 percent.

6. Although it was decided not to recommend a change from T. M. No. Calif. 216 to the proposed modified ASTM 1557 test method at this time because of manpower reductions and the departments present financial situation, it is important to stress the desirability of eventually adopting the proposed method. The most desirable feature of a change in procedure are:

a. The proposed modified ASTM 1557 method conforms more closely to the accepted national standard ASTM 1557 procedure than the present T.M. No. Calif. 216.

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b. The same test apparatus is used for the modified ASTM 1557 as the standard version. This equipment would enable California to perform the standard ASTM 1557 procedure when requested by other agencies.

c. In cases where a rock correction is required, an easier, more rapid procedure is applied with the proposed modified ASTM method which eliminates the mathematical correction now employed with T.M. No. Calif. 216.

7. The data in this study indicated slightly better test repeatability for the manual compaction procedure when all tests were performed in one laboratory under ideal conditions.

The researchers believe the mechanical compactor will have better repeatability when compared to a large number of test operators throughout the State.

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RECOMMENDATIONS

The results of this study indicate that the mechanical compactor should be established as the standard and an operator should be certified by comparing his results with that of the mechanical compactor using a suitable soil. Criteria for operator certification are appended.

It is felt that specifications such as linear dimensions, weight, and height of drop of the rammer are sufficient to ensure proper calibration.

It is recommended that additional research be performed to determine if the maximum density portion of Test Method No. Calif. 312 for cement treated base (CTB) could be incorporated into either the existing Test Method No. Calif. 216 or a modified version of the ASTM 1557 test method. This research should be completed before a final decision is made relative to possible adoption of a revised ASTM test method or retention of the existing procedure.

Although a 4-inch diameter mold was used exclusively in this study for the proposed ASTM test procedure, the researchers recommend that a 6-inch diameter mold be adopted in the ASTM 1557 Test Method for testing materials containing 10% or more of retained 3/4-inch rock. The 6-inch diameter mold was not included in the California modified version of ASTM 1557 (shown in Appendix C) for testing plus 3/4-inch material. However, it should be added and made mandatory if the additional research is favorable and California adopts the modified ASTM test method.

It is recommended that the mechanical rammer be adopted as the standard to certify test operators. This should result in better test repeatability, reproducibility and reduce the number of retests.

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IMPLEMENTATION

The mechanical rammer will be adopted as a supplemental compaction device by the Transportation Laboratory. Adoption of this device should result in increased production and less cost per test.

Operator certification will be implemented during the California D.O.T. District's annual certification program. The method outlined in Appendix B will be used when the modified ASTM 1557 procedure is adopted. In the interim a similar method for certifying operators for T. M. Calif. 216 will be developed utilizing the mechanical rammer as the standard.

When the decision is made to adopt the modified version of ASTM 1557, implementation would begin by equipping all districts to perform the test method as proposed herein. The second step would embrace training and familiarization of personnel prior to the actual changeover. The third and final step involves the complete changeover to this method of test maximum soil density determination. The test method would be stipulated in the Special Provisions and incorporated in the Standard Specifications at a later date. Appropriate changes would also be made in the Construction Manual.

A request has been made to ASTM to adopt the modified (California) version as a standard.

A lead time of six months to one year is suggested in order to allow cities, counties, and private engineers to acquire test equipment and familarize themselves with the new test.

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MECHANICAL COMPACTOR

Description

A fully automatic, hydraulically operated compactor was fabricated according to specifications prepared by the researchers (Appendix A). Some of the features of the compactor include an automatic soil loader, use of a 5.5 or a 10.0 pound rammer, variable height of drop of the rammer from 12 to 18 inches, use of a 3 to 6 inch diameter mold and a random pattern of the rammer during compaction of the sample. A photograph of the compactor is shown on Figure 1.

The automatic loading feature of the machine was not entirely satisfactory. The California and ASTM procedures require the soil to be compacted in the mold in 5 equal layers. The belt feed type of mechanism using wet soil and aggregates showed as much as a 30 percent variation between increments. Therefore, to implement this study all soils were hand loaded so that each of the 5 lifts had equal amounts of material.

Calibration Procedures

The manual and mechanical rammer used in this study and conforming to ASTM 1557-70 was calibrated according to ASTM D2168. This method showed that when the weight of hammer and height of drop were the same for both type rammers, the readings for the deformed lead slugs were the same. The data is displayed on the following Table 1.

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TABLE 1

Length Deformation of Lead Calibration Cylinders
(Average of 10 Tests)
(Deformation in Inches)

Manual Rammer				Mechanical Rammer			
$\bar{X}$	Before Deformation	After Deformation	Difference	$\bar{X}$	Before Deformation	After Deformation	Difference
	0.610	0.282	0.328		0.611	0.285	0.326

Analysis of Data

Excessive sidewall friction from the guidesleeves could possibly indicate a difference in compactive effort between the manual rammer and the mechanical rammer. However, this should not be a problem with a free falling rammer on properly designed equipment.

ASTM D2168 further suggests that a mechanical compactor be qualified by comparing test results obtained with it to those obtained with the manual compactor on clay soil. The researchers believe that this is a questionable approach because of the greater number of variables inherent in the manual method compared to the mechanical procedure.

In order to investigate this premise, a series of tests with ASTM D2168 were performed with a clean manual rammer held vertically, slightly tilted, and also with some soil sticking to the guidesleeve. The following Table 2 shows resulting data.

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TABLE 2

Length Deformation of Lead Calibrating Cylinders

(Average of 5 Tests)

Rammer Condition	From Horizontal Position	Deformation Inches	Compactive Effort* Ft-lb/Ft^3
Clean rammer and guide	90°	0.328	56,250
Clean rammer and guide	85°	0.302	51,791
Clean rammer and guide	80°	0.296	50.762
Dirty rammer and guide	90°	0.320	54,878
Dirty rammer and guide	85°	0.296	50,762

As shown by Table 2, even minor variations in the manual procedure can result in up to a 10% reduction in energy input to the soil specimen.

*Compactive Effort = 25 blows per layer x 5 layers
x 1.5 foot drop x 10 lb hammer
x 30 (0.0333 Ft^3 mold)

The effort for other than the clean rammer was calculated by a direct relationship as shown by the following example:

$$\frac{0.328\text{ in.}}{0.302\text{ in.}} = \frac{56,250}{x}\text{ ft-lb/Ft}^3 \quad x = 51,791\text{ Ft-lb/Ft}^3$$

In actual practice, there could be instances where soil sticking to the guide could have an even greater effect on the compactive effort than was shown in this study. In other cases some operators might tend to speed up the test and in doing so lift the rammer higher than the specified 18 inches, or tilt the rammer. The mechanical compactor precludes such procedural deviation.

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COMPARATIVE SOIL TESTS: ASTM 1557 VERSUS CALIF. 216

Procedure

A total of 17 different soils and aggregates were obtained and used for this study. The materials are identified as Samples 1 through 17 and their grading analyses are shown in Figure 2.

A moisture density curve was developed for each soil sample to determine optimum moisture and test maximum dry density. Specimens were fabricated by the T. M. No. Calif. 216 and ASTM 1557-70 procedures using mechanical and manual compaction. The test data are shown on Figures 3 through 19 and summarized on Figure 20 (density) and Figure 21 (optimum moisture).

Test Maximum Density

The data on Figure 20 indicate slightly higher densities by the ASTM 1557 method versus Calif. 216 for most materials except clays and those requiring a rock correction, which were lower.

The clayey soils tests by the ASTM 1557 method reflected lower laboratory densities than those utilizing California No. 216. This would, of course, result in a slightly lower field density to achieve specification compaction requirements if ASTM 1557 were adopted. The lower field densities are not expected to result in any significant loss in soil strength or increase in settlement.

Similarly, the soils consisting of a mix of silt, sand, and clay (Samples 6 and 12) reflected slightly higher densities and lower optimum moisture contents with the ASTM 1557 method.

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Again, no problems are anticipated in meeting field compaction specifications with these materials utilizing the ASTM Method since it is relatively easy to achieve specification compaction requirements for these soils in the field. From a strength standpoint, the additional compaction may be helpful since these soils are susceptible to strength loss with increased moisture content. Aggregate base and subbase lab densities were slightly lower when compacted by the ASTM 1557 method. This deviation from Calif. Test Method 216 is not considered great enough to have any significant effect on the quality of the finished product. Also, these materials are relatively easy to compact to specification density.

Optimum Moisture

The data on Figure 21 indicates some difference in optimum moisture between the Calif. 216 and ASTM 1557, depending on the soil type. However, no problem is anticipated since the optimum moisture is not determined during the test for relative compaction when using the wet method.

Determination of moisture content must be made for aggregate base materials to establish pay quantities. Water in excess of one percentage point more than the optimum moisture determination by Calif. 216 is not paid for. The data indicates the optimum moisture by the ASTM 1557 method is generally about one percent lower than the Calif. 216. Thus less water would be paid for if the ASTM 1557 were used. This would not appear to present any problems.

Oversize Rock Considerations

A different compaction procedure is used for T.M. No. Calif. 216 than for the ASTM 1557-70 test method when compacting

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materials that have plus 3/4-inch rock. The former applies a mathematical correction to the compacted specimen when the material contains 10% or more of retained 3/4-inch rock, depending on the specific gravity and amount of rock. In the ASTM 1557-70 method, a rock correction is not applied to the compacted specimen. The material is scalped on the 2-inch sieve and the 2-inch by 3/4-inch material is replaced by an equal amount of 3/4-inch by No. 4 material. It is not stipulated in the ASTM 1557 procedure as to when the oversized material will be replaced with 3/4-inch by No. 4 material. It simply states that if it is advisable to maintain the same percentage of coarse material, replace the plus 3/4-inch with the smaller material.

The proposed test method will incorporate the "scalping" on the 2-inch sieve from ASTM 1557 and specify the 10% or more plus 3/4-inch rock from No. T. M. Calif. 216 as the controlling factor for applying the rock correction.

Replicate Tests

In order to develop some criteria for precision of the compaction tests in this study, a series of replicate tests were performed. Eight replicate specimens were compacted at optimum moisture for the Calif. 216 method. These tests were repeated for the ASTM 1557 method using the manual and mechanical procedures. The average differences of the ASTM 1557 methods from Calif. 216 are shown in Figure 22.

Figure 23 shows a summary of the standard deviation and range of test densities for the 8 replicate specimens compacted by the three procedures. The variance was calculated from the standard deviations and averaged for the different procedures. It is 0.56, 0.46, and 0.61, for the Calif. 216, ASTM 1557 manual and mechanical compaction, respectively.

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Contrary to what would normally be expected, the mechanical procedure showed slightly greater variability than the manual procedure, possibly due to the limited number of tests and the fact that the manual procedure was conducted under carefully controlled laboratory conditions using highly qualified operators.

Tentative Test Method

Based on this study, a tentative test method was proposed (see Appendix C) as a possible replacement for Test Method No. Calif. 216. This method would incorporate the better features of T. M. No. Calif. 216 and ASTM 1557-70. Although the 4-inch diameter mold was used exclusively in this research for the ASTM 1557-70 test data, the researchers believe that material with 10 percent or more of plus 3/4-inch rock should be tested with a 6-inch diameter mold to obtain more accurate and realistic results. If the proposed modified ASTM 1557 procedure is adopted as California's test method, the 6-inch mold would be mandatory for materials having 10 percent or more 3/4-inch sieve size. The use of the 6-inch diameter mold for a specified percentage of retained 3/4-inch material is being considered by the ASTM Committee for an ASTM 1557-76 revision.

The maximum density testing of CTB will be included in the tentative test method if satisfactory results are obtained from recommended future research studies comparing data for Test Methods No. Calif. 312, 216 and the modified ASTM 1557.

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CERTIFICATION OF TEST OPERATORS

The California Transportation Laboratory has conducted a correlation testing program for the past few years with laboratories from various cities and counties participating as well as those from California Department of Transportation Districts. Under this program replicate samples of the same soil were submitted to each laboratory for comparison testing for maximum density using T.M. No. Calif. 216. Other test parameters were also determined. Based on the poor correlation results for maximum density indicated by this program, the researchers believe that a better method of certifying test operators is needed to assure that the test for maximum density is being performed as correctly and accurately as possible.

ASTM D2168-72 allows 2 percent variation of mechanical compaction test results from the manual compaction test results. This tolerance appears to be reasonable with respect to the test data obtained in this study. However, it is recommended that the mechanical procedure be accepted as the standard and test operators be certified by correlating to the mechanical procedure. This type of approach would lessen the number of variables influencing the test results.

A tentative method for certifying test operators has been drafted and is attached to this report as Appendix II.

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1. Hveem, F. N., "Maximum Density and Optimum Moisture of Soils - What Do These Terms Mean?", California Division of Highways, Materials and Research Department, January 1957.

2. Sherman, George B., Watkins, Robert O., and Prysock, Rogel H., "A Statistical Analysis of Embankment Construction", California Division of Highways, Materials and Research Department, January 1967.

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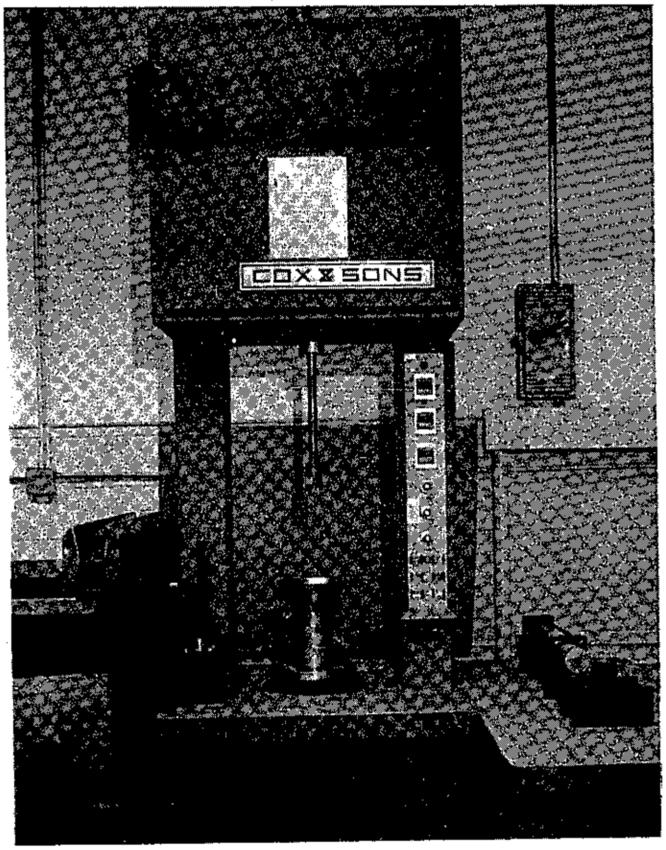

Figure 1

Mechanical Compactor

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Figure 2

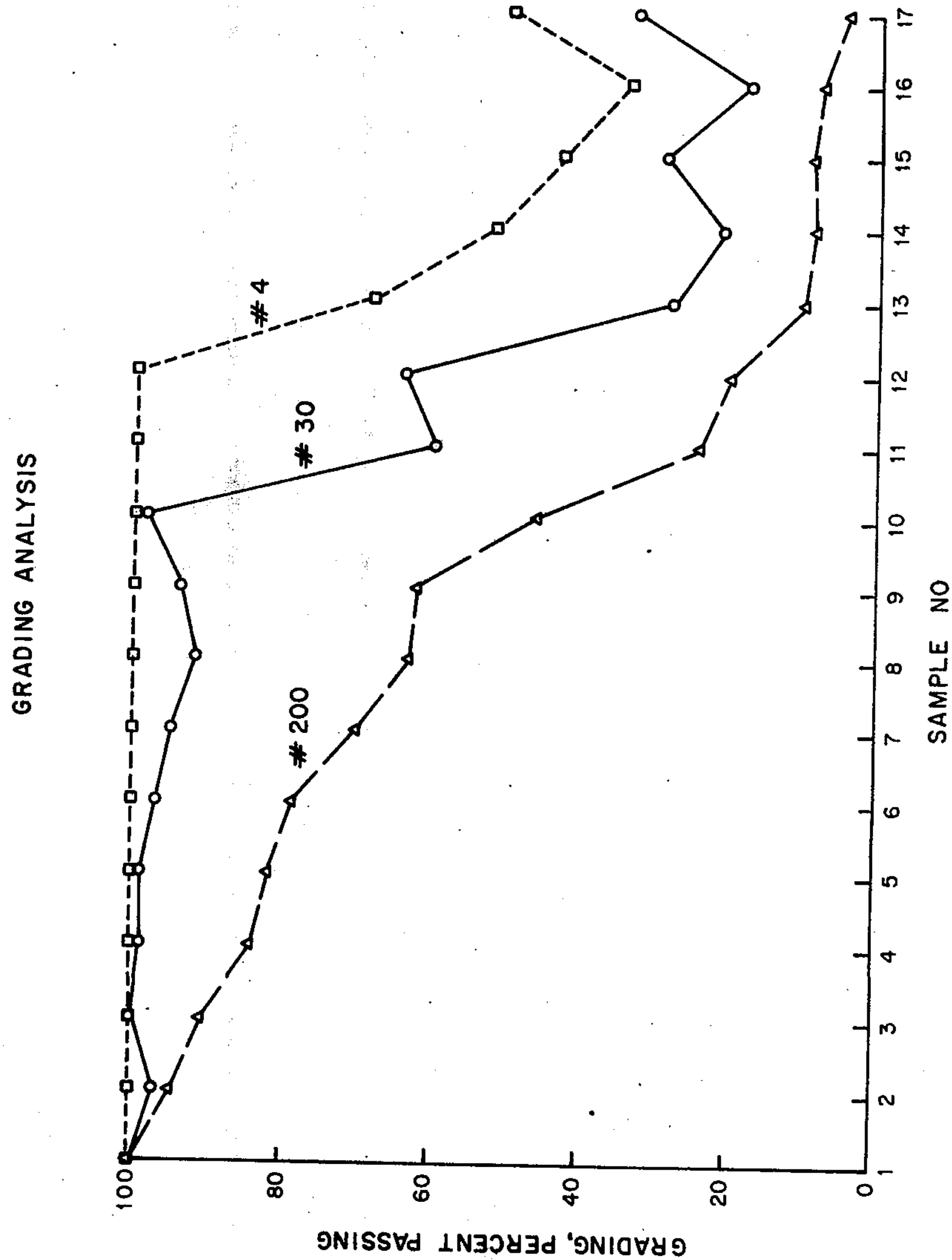

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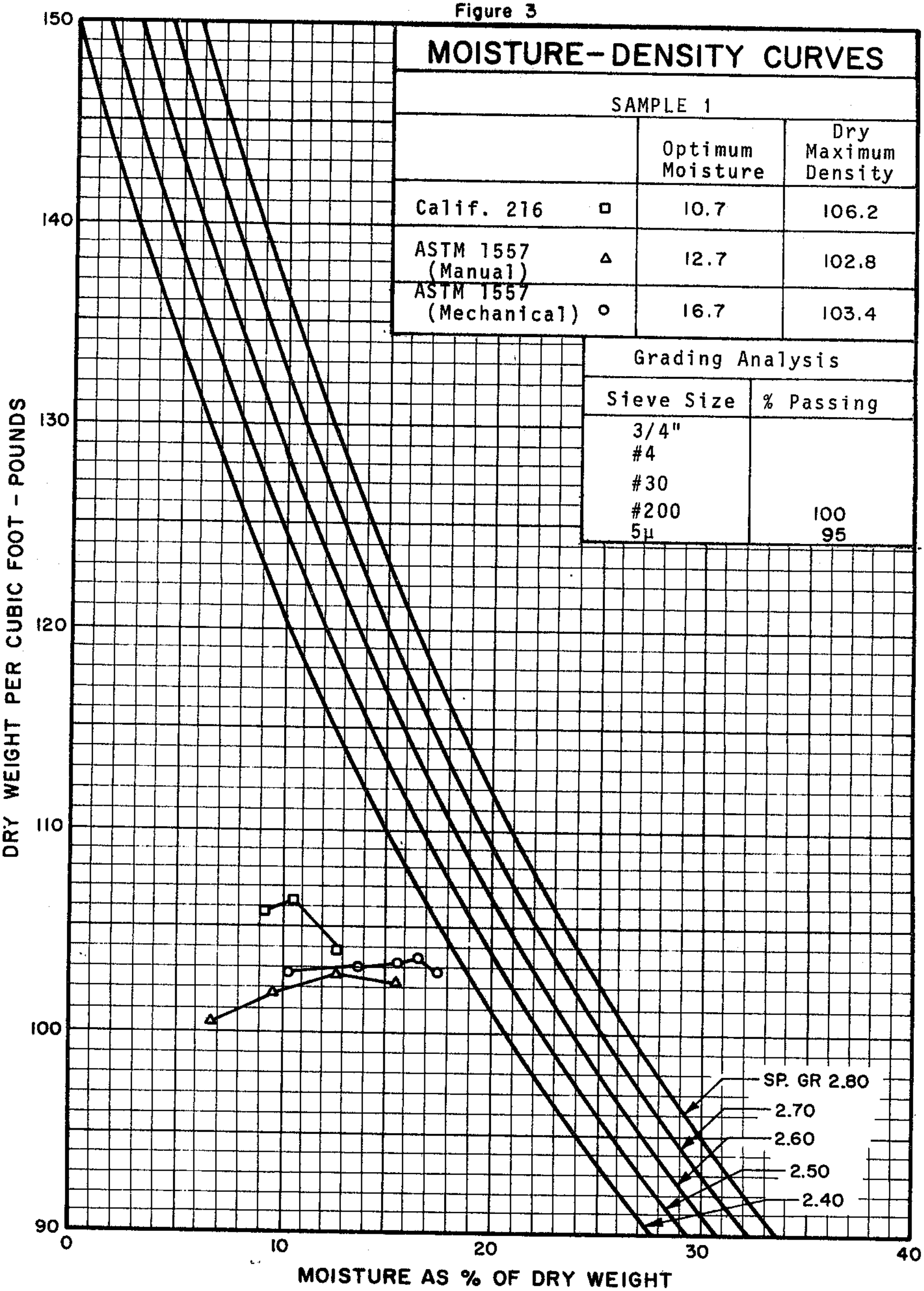
Figure 3



SAMPLE 1

		Optimum Moisture	Dry Maximum Density
Calif. 216	□	10.7	106.2
ASTM 1557 (Manual)	△	12.7	102.8
ASTM 1557 (Mechanical)	○	16.7	103.4

Grading Analysis

Sieve Size	% Passing
3/4"	
#4	
#30	
#200	100
5µ	95

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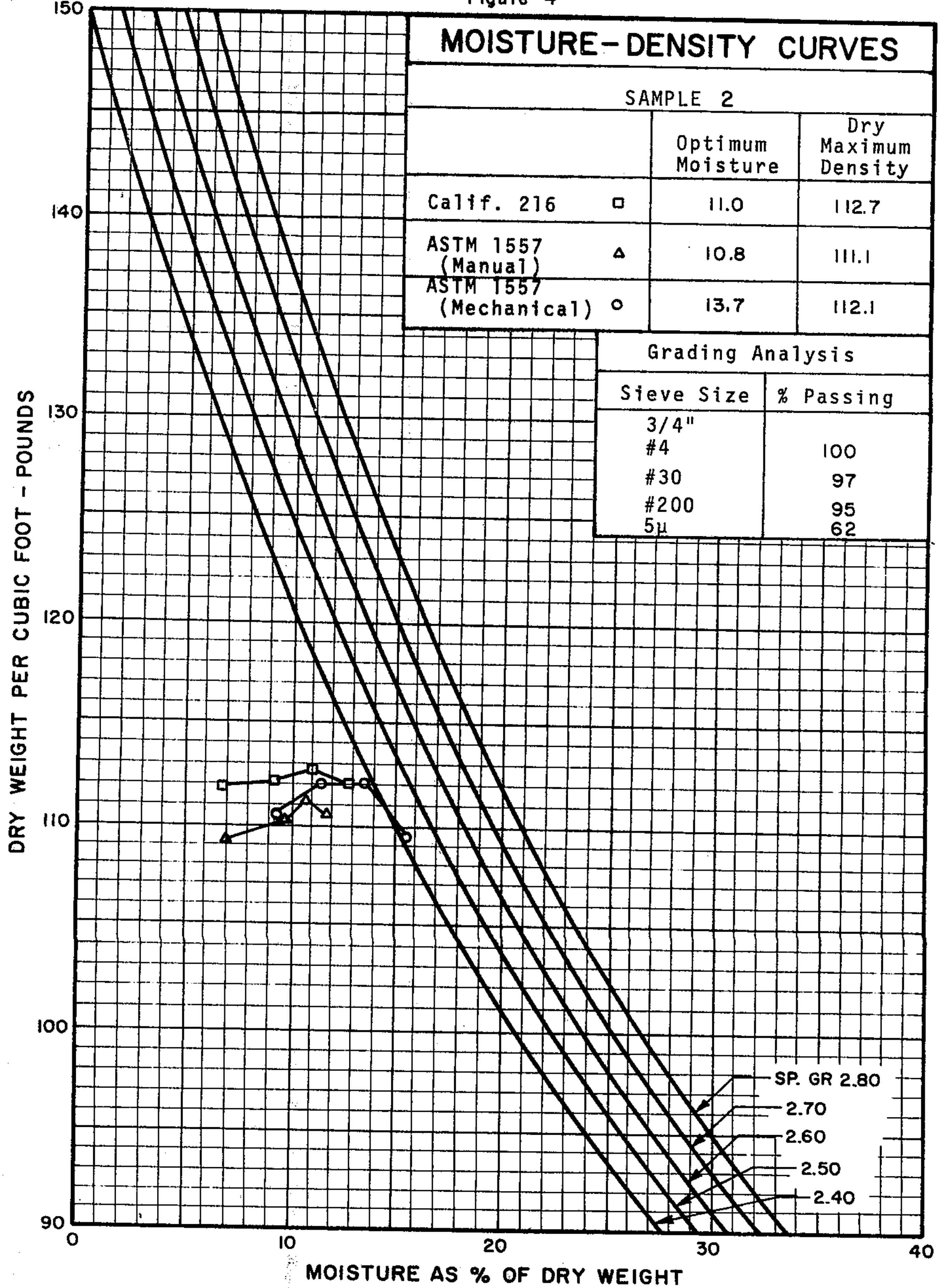
Figure 4



SAMPLE 2

		Optimum Moisture	Dry Maximum Density
Calif. 216	□	11.0	112.7
ASTM 1557 (Manual)	△	10.8	111.1
ASTM 1557 (Mechanical)	○	13.7	112.1

Grading Analysis

Sieve Size	% Passing
3/4"	
#4	100
#30	97
#200	95
5μ	62

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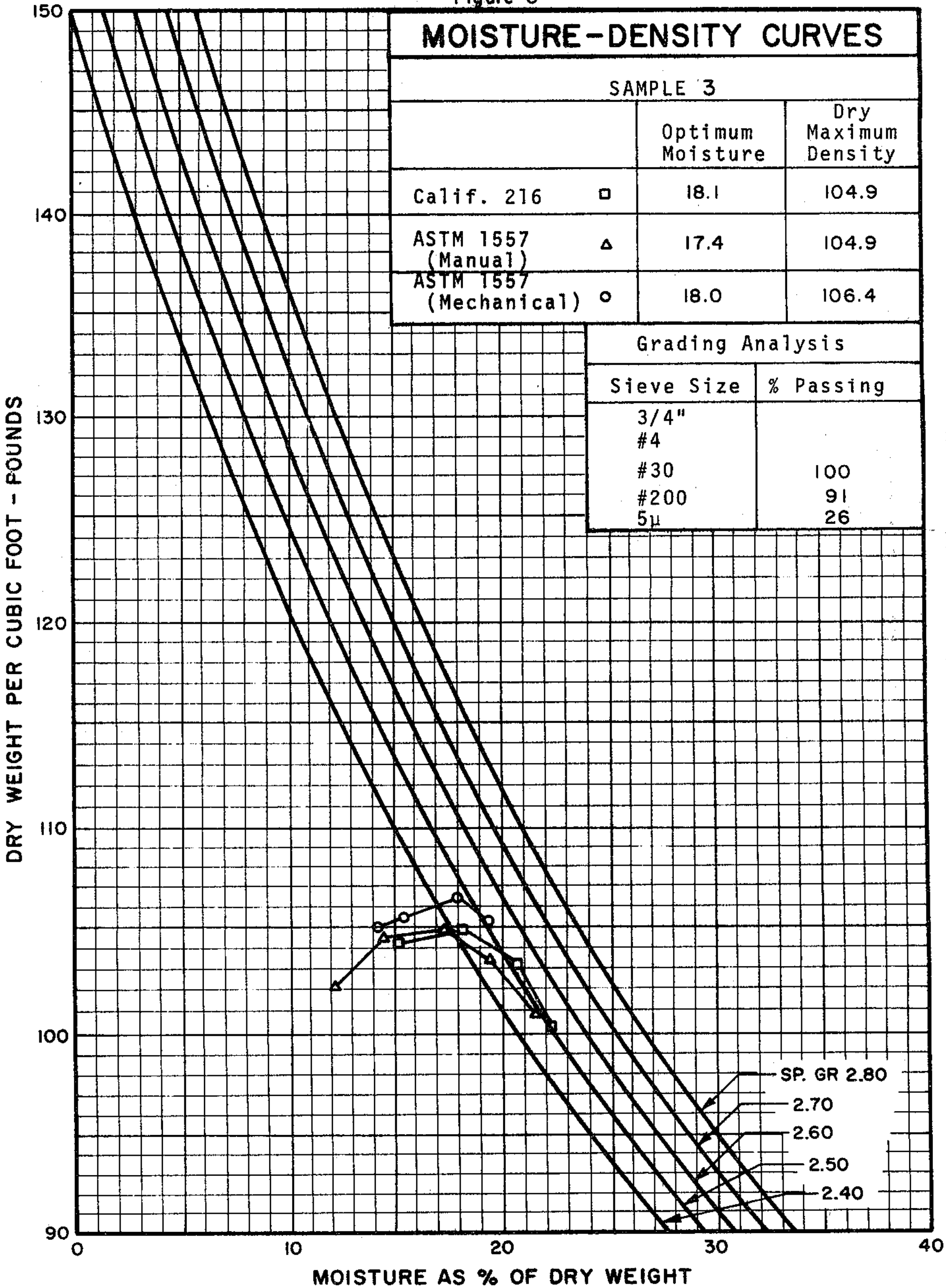
Figure 5



SAMPLE 3

		Optimum Moisture	Dry Maximum Density
Calif. 216	□	18.1	104.9
ASTM 1557 (Manual)	△	17.4	104.9
ASTM 1557 (Mechanical)	○	18.0	106.4

Grading Analysis

Sieve Size	% Passing
3/4"	
#4	
#30	100
#200	91
5µ	26

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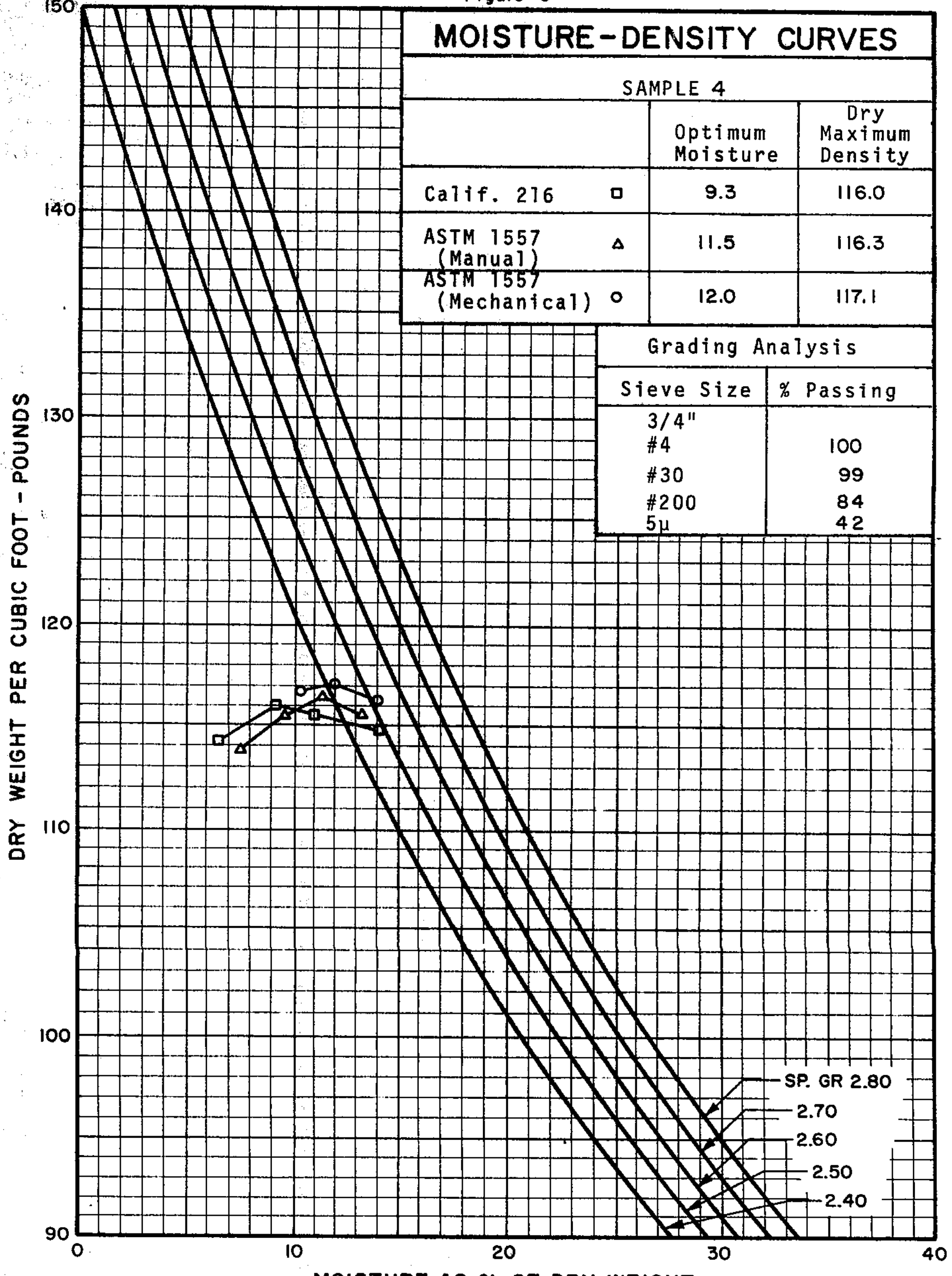
Figure 6



MOISTURE-DENSITY CURVES

SAMPLE 4

		Optimum Moisture	Dry Maximum Density
Calif. 216	□	9.3	116.0
ASTM 1557 (Manual)	△	11.5	116.3
ASTM 1557 (Mechanical)	○	12.0	117.1

Grading Analysis

Sieve Size	% Passing
3/4"	
#4	100
#30	99
#200	84
5μ	42

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Figure 7

MOISTURE-DENSITY CURVES

SAMPLE 5

		Optimum Moisture	Dry Maximum Density
Calif. 216	□	11.3	114.7
ASTM 1557 (Manual)	△	13.4	116.7
ASTM 1557 (Mechanical)	o	12.8	116.1

Grading Analysis

Sieve Size	% Passing
3/4"	
#4	100
#30	99
#200	82
5μ	35

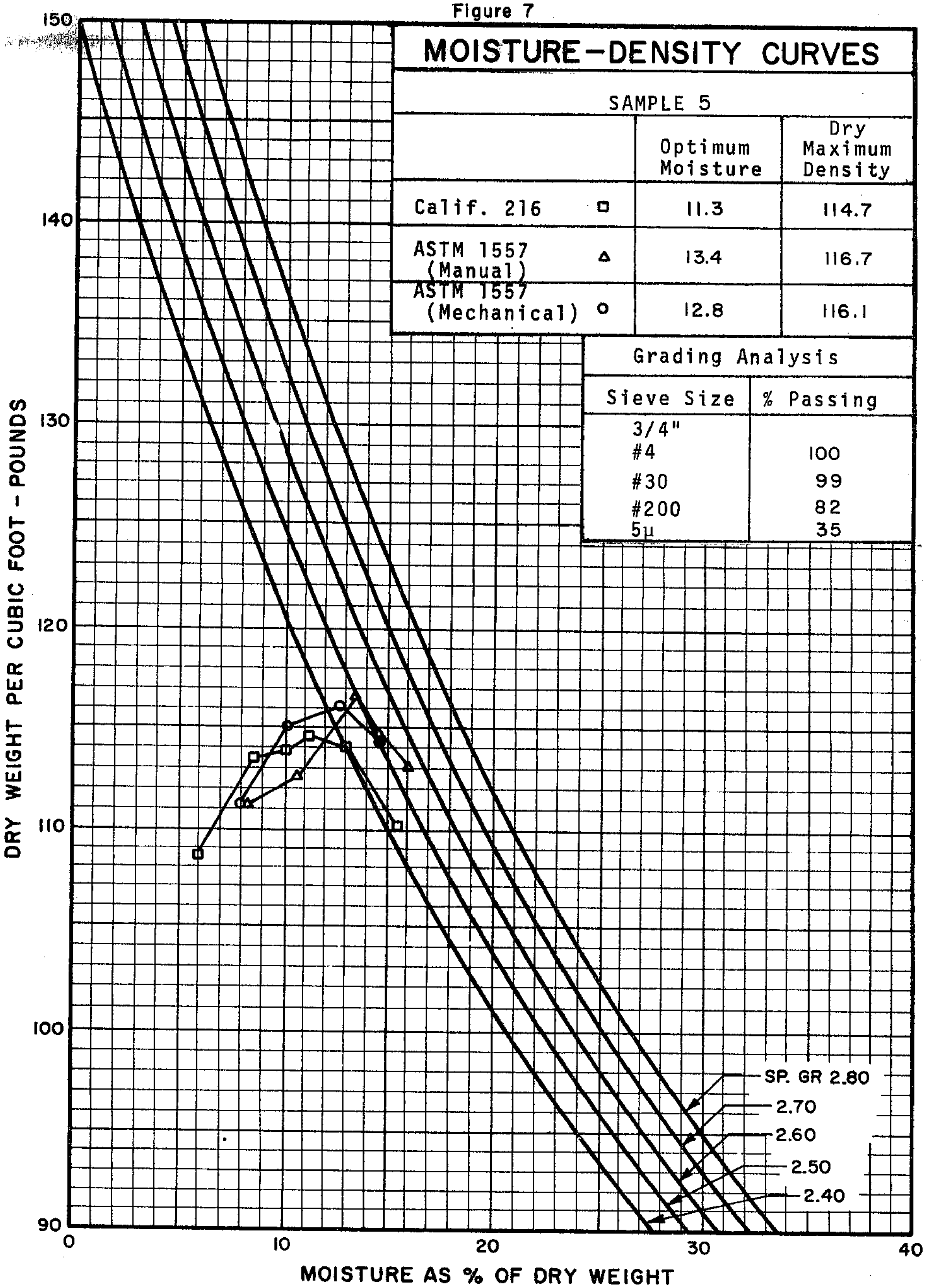

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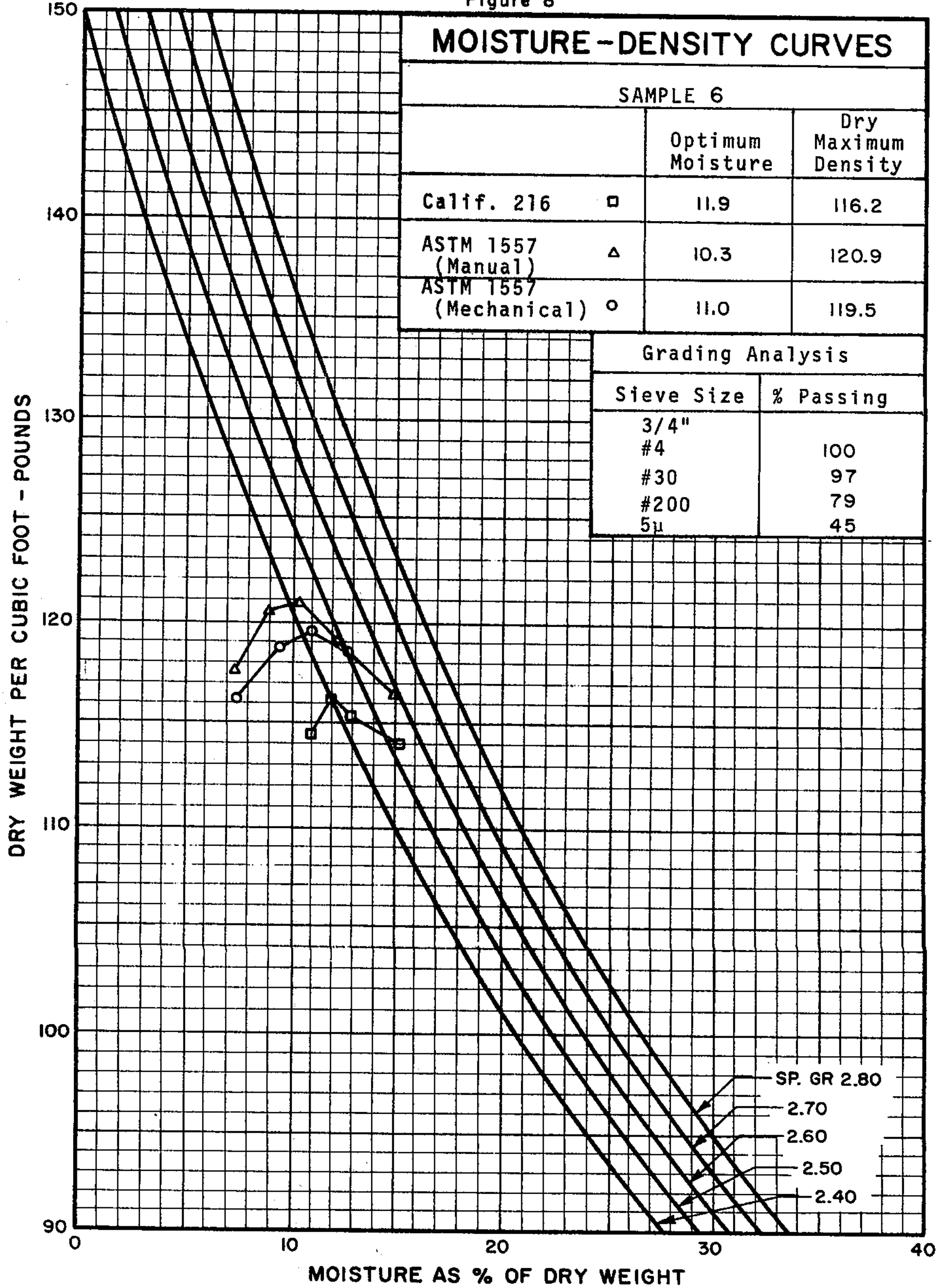
Figure 8



SAMPLE 6

	Optimum Moisture	Dry Maximum Density
Calif. 216 □	11.9	116.2
ASTM 1557 (Manual) △	10.3	120.9
ASTM 1557 (Mechanical) ○	11.0	119.5

Grading Analysis

Sieve Size	% Passing
3/4"	
#4	100
#30	97
#200	79
5µ	45

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Figure 9

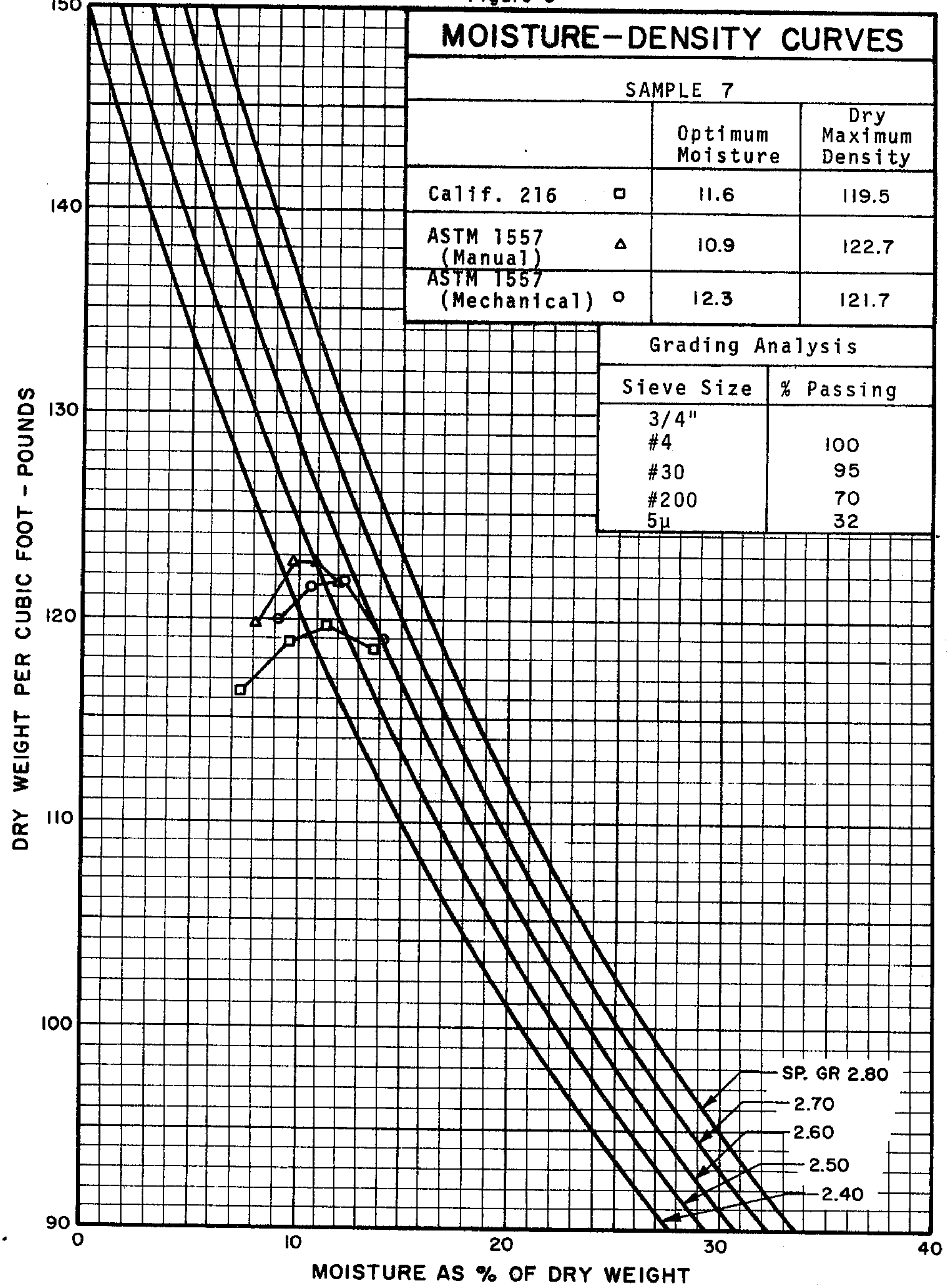

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Figure 10

MOISTURE-DENSITY CURVES

SAMPLE 8

		Optimum Moisture	Dry Maximum Density
Calif. 216	□	13.0	117.1
ASTM 1557 (Manual)	△	13.6	115.3
ASTM 1557 (Mechanical)	○	9.7	116.6

Grading Analysis

Sieve Size	% Passing
3/4"	
#4	100
#30	92
#200	63
5µ	34

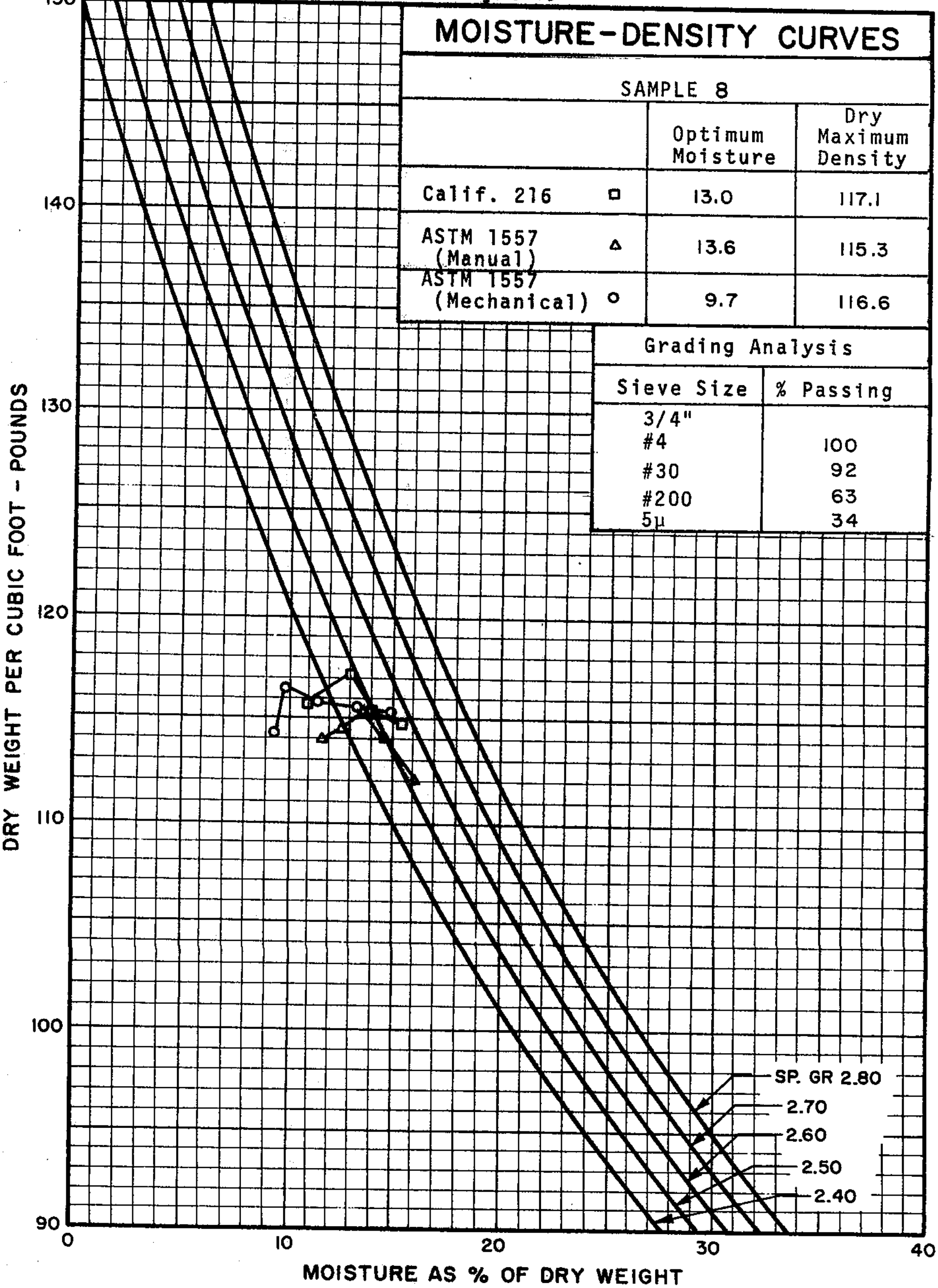

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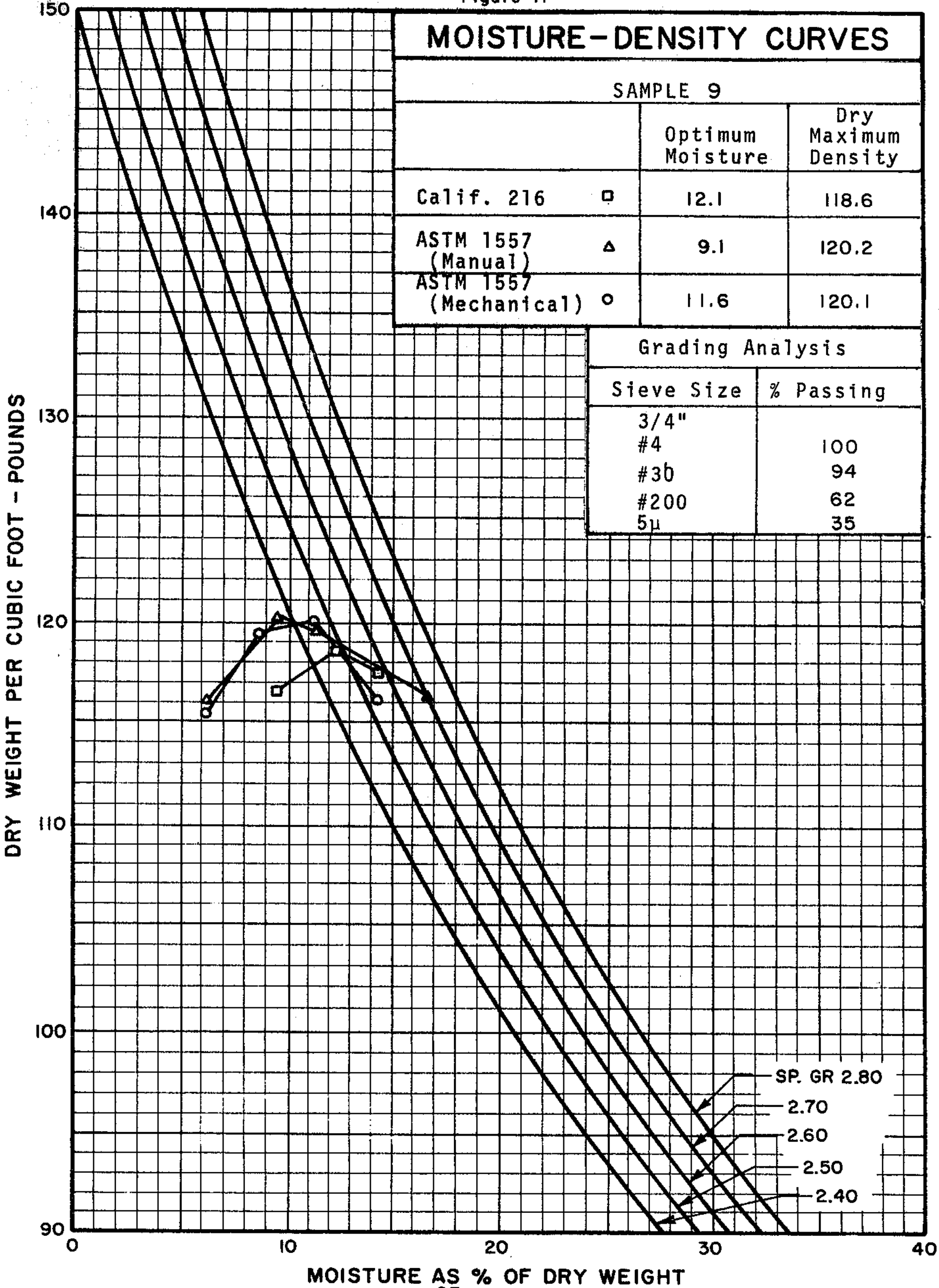
Figure 11

MOISTURE-DENSITY CURVES



SAMPLE 9

	Optimum Moisture	Dry Maximum Density
Calif. 216 □	12.1	118.6
ASTM 1557 (Manual) △	9.1	120.2
ASTM 1557 (Mechanical) ○	11.6	120.1

Grading Analysis

Sieve Size	% Passing
3/4"	
#4	100
#30	94
#200	62
5µ	35

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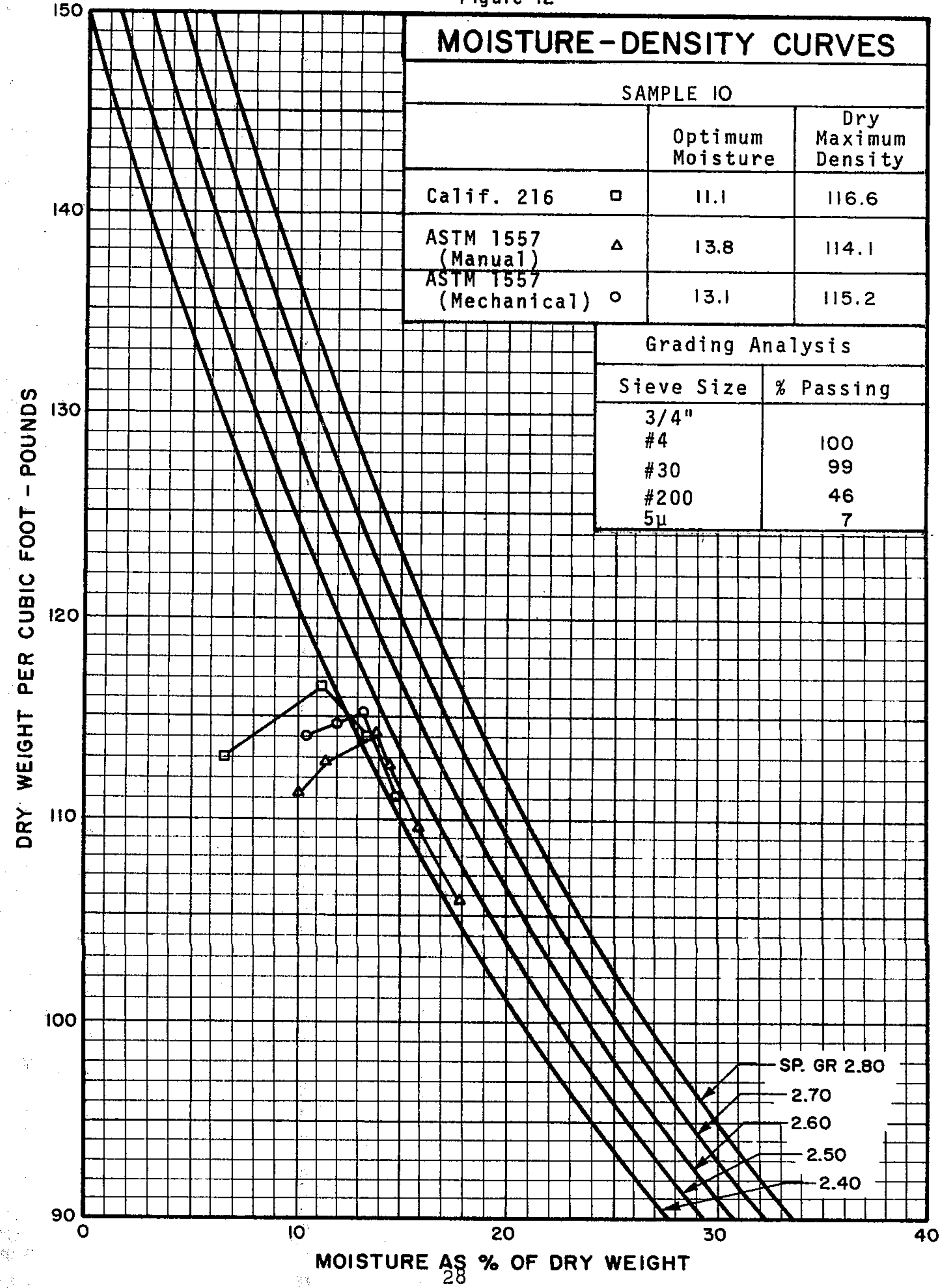
Figure 12



SAMPLE 10

	Optimum Moisture	Dry Maximum Density
Calif. 216 □	11.1	116.6
ASTM 1557 (Manual) △	13.8	114.1
ASTM 1557 (Mechanical) ○	13.1	115.2

Grading Analysis

Sieve Size	% Passing
3/4"	
#4	100
#30	99
#200	46
5µ	7

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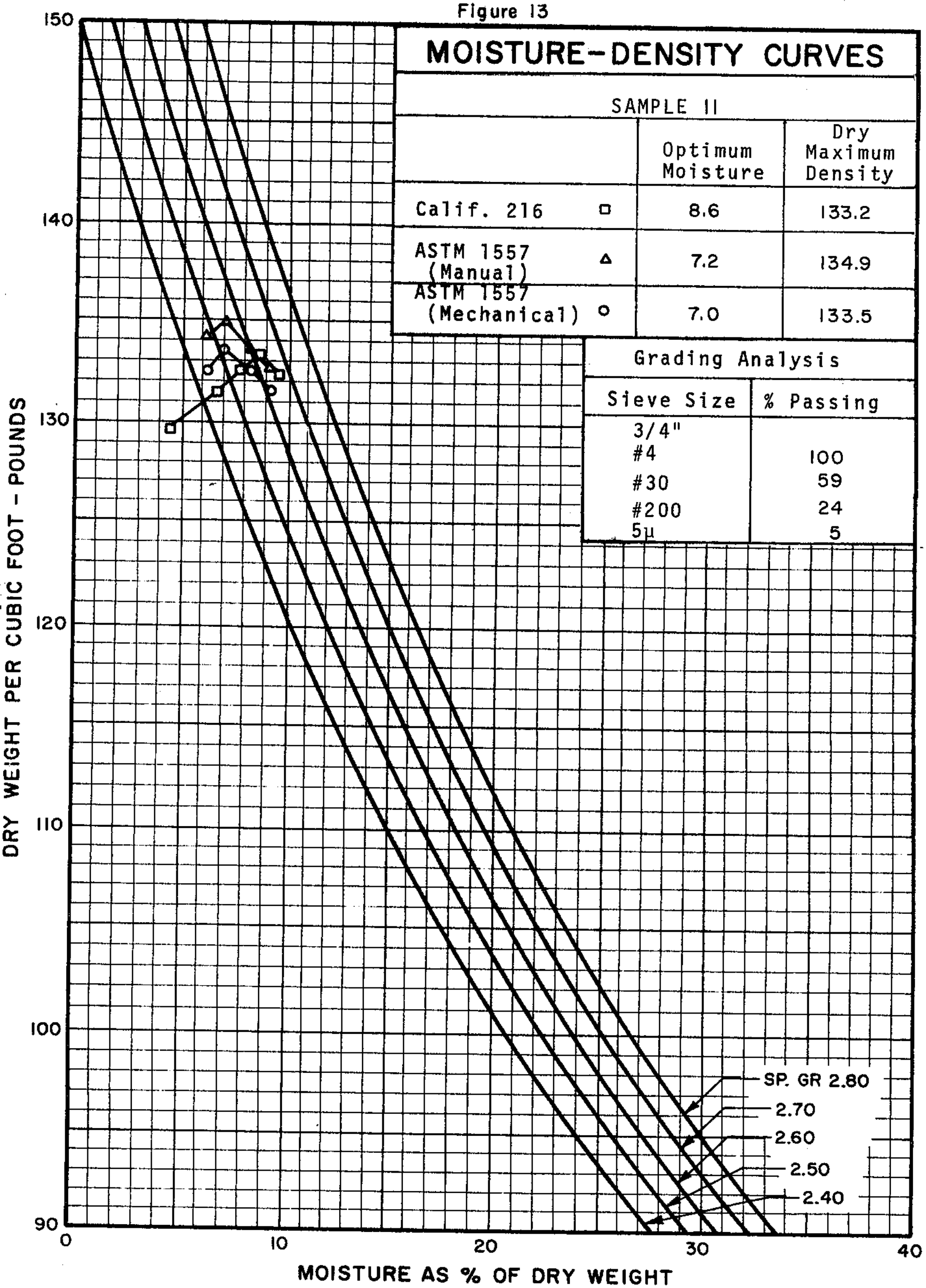
Figure 13

MOISTURE-DENSITY CURVES



SAMPLE II

	Optimum Moisture	Dry Maximum Density
Calif. 216 □	8.6	133.2
ASTM 1557 (Manual) △	7.2	134.9
ASTM 1557 (Mechanical) ○	7.0	133.5

Grading Analysis

Sieve Size	% Passing
3/4"	
#4	100
#30	59
#200	24
5µ	5

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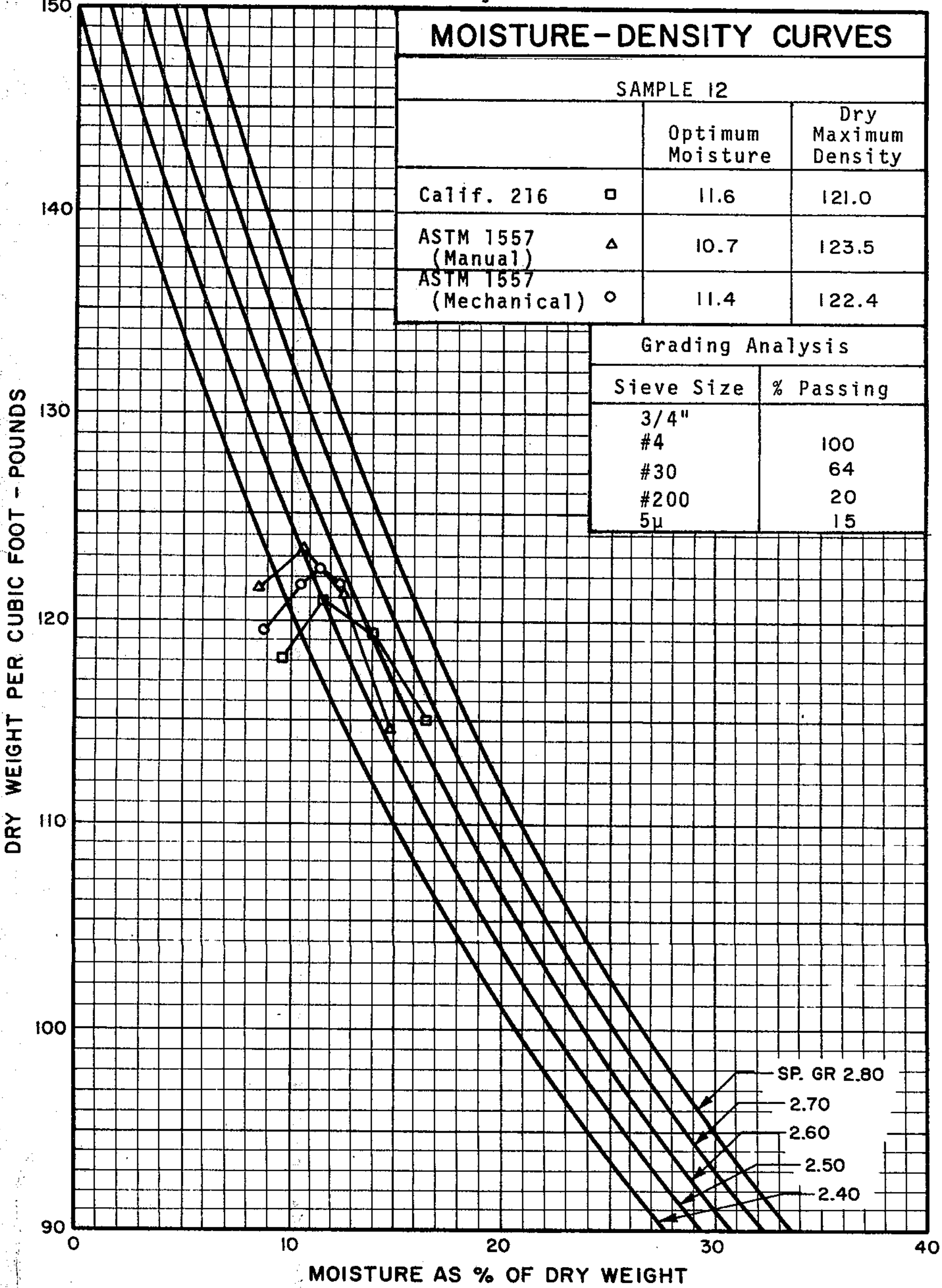
Figure 14

MOISTURE-DENSITY CURVES



SAMPLE 12

		Optimum Moisture	Dry Maximum Density
Calif. 216	□	11.6	121.0
ASTM 1557 (Manual)	△	10.7	123.5
ASTM 1557 (Mechanical)	○	11.4	122.4

Grading Analysis	
Sieve Size	% Passing
3/4"	
#4	100
#30	64
#200	20
5µ	15

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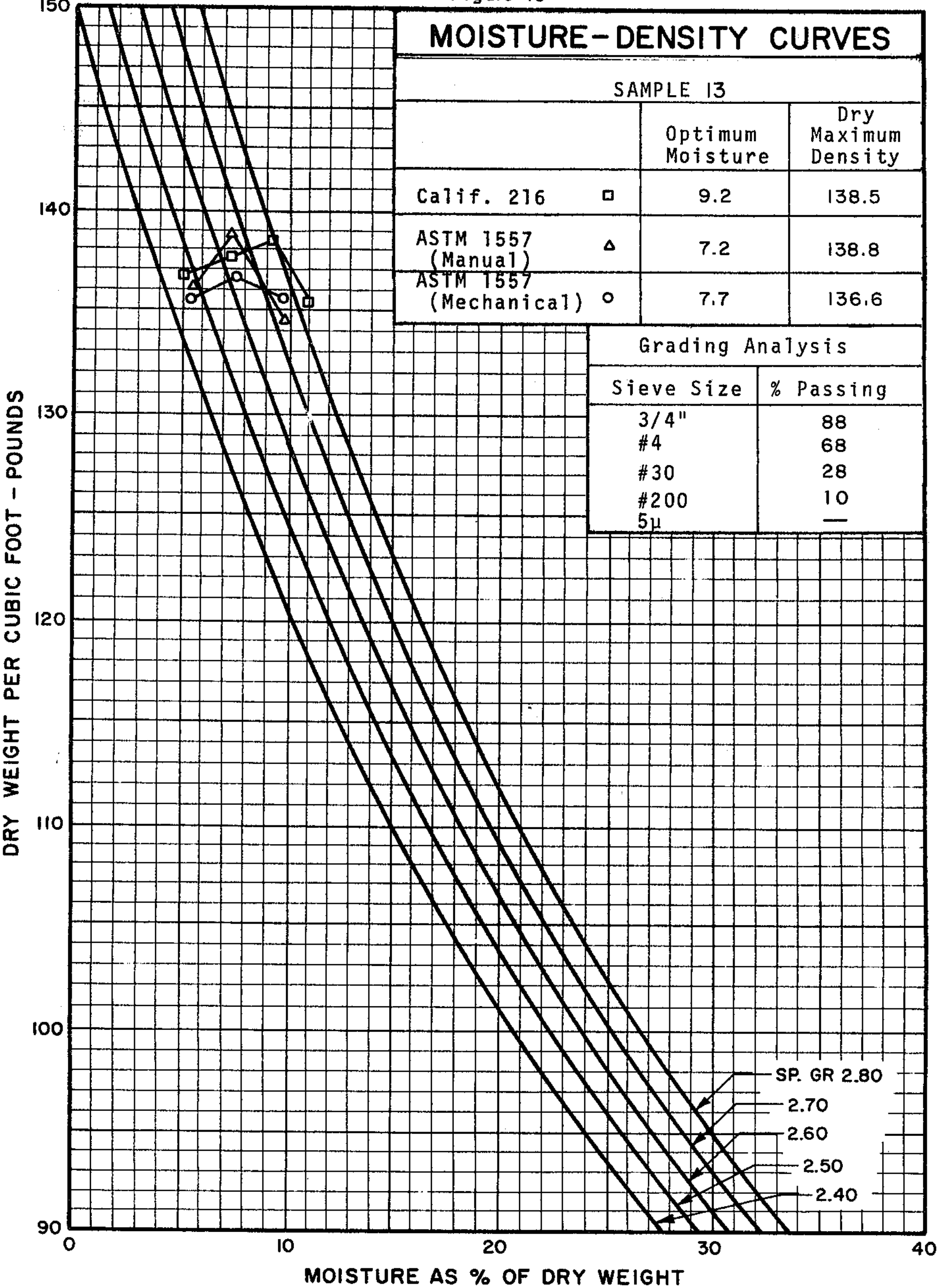
Figure 15

MOISTURE-DENSITY CURVES



SAMPLE 13

		Optimum Moisture	Dry Maximum Density
Calif. 216	□	9.2	138.5
ASTM 1557 (Manual)	△	7.2	138.8
ASTM 1557 (Mechanical)	○	7.7	136.6

Grading Analysis

Sieve Size	% Passing
3/4"	88
#4	68
#30	28
#200	10
5μ	—

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Figure 16

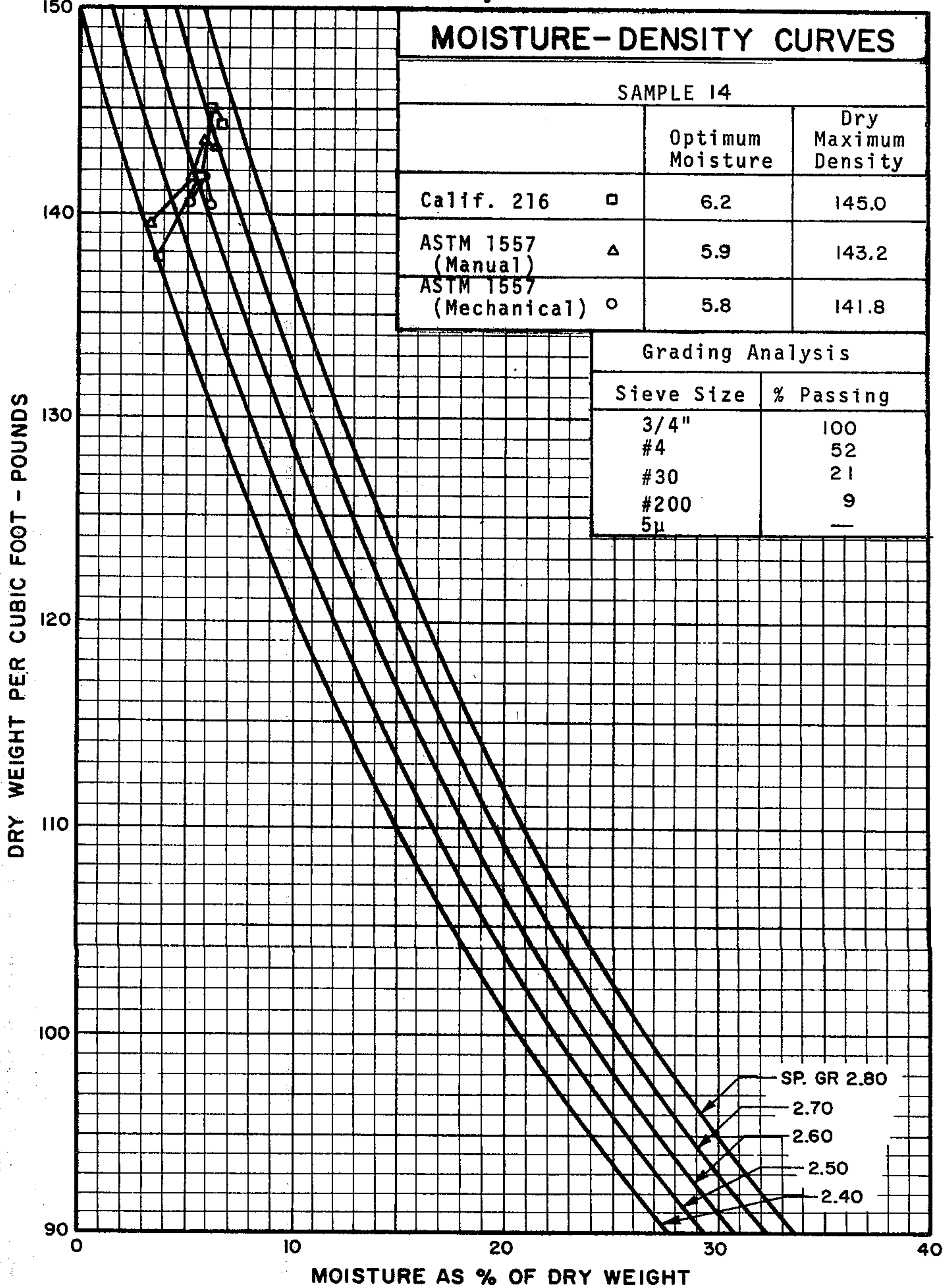

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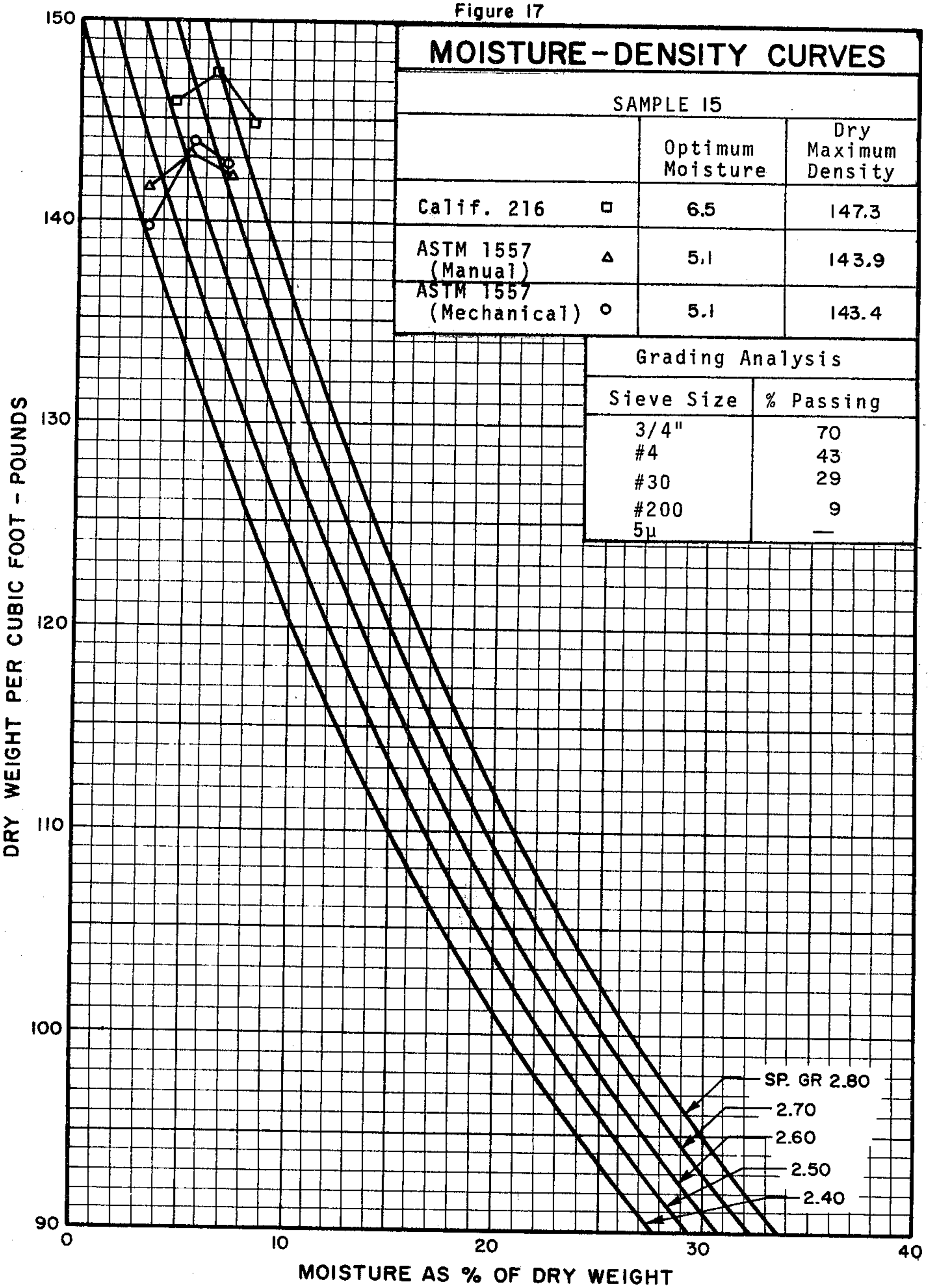
Figure 17



	Optimum Moisture	Dry Maximum Density
Calif. 216 □	6.5	147.3
ASTM 1557 (Manual) △	5.1	143.9
ASTM 1557 (Mechanical) ○	5.1	143.4

Grading Analysis

Sieve Size	% Passing
3/4"	70
#4	43
#30	29
#200	9
5μ	—

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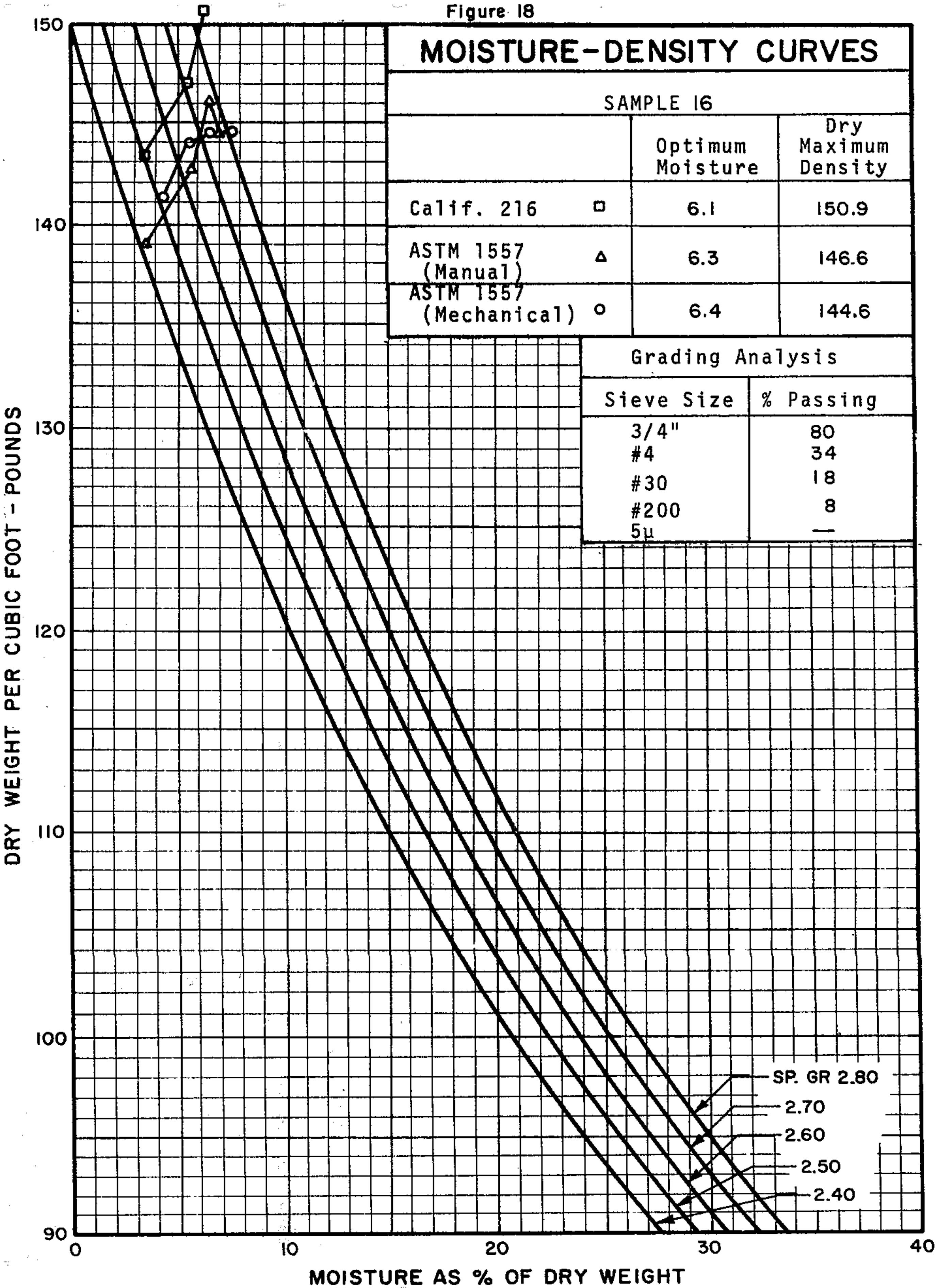
Figure 18

MOISTURE-DENSITY CURVES



SAMPLE 16

		Optimum Moisture	Dry Maximum Density
Calif. 216	□	6.1	150.9
ASTM 1557 (Manual)	△	6.3	146.6
ASTM 1557 (Mechanical)	○	6.4	144.6

Grading Analysis

Sieve Size	% Passing
3/4"	80
#4	34
#30	18
#200	8
5µ	—

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Figure 19

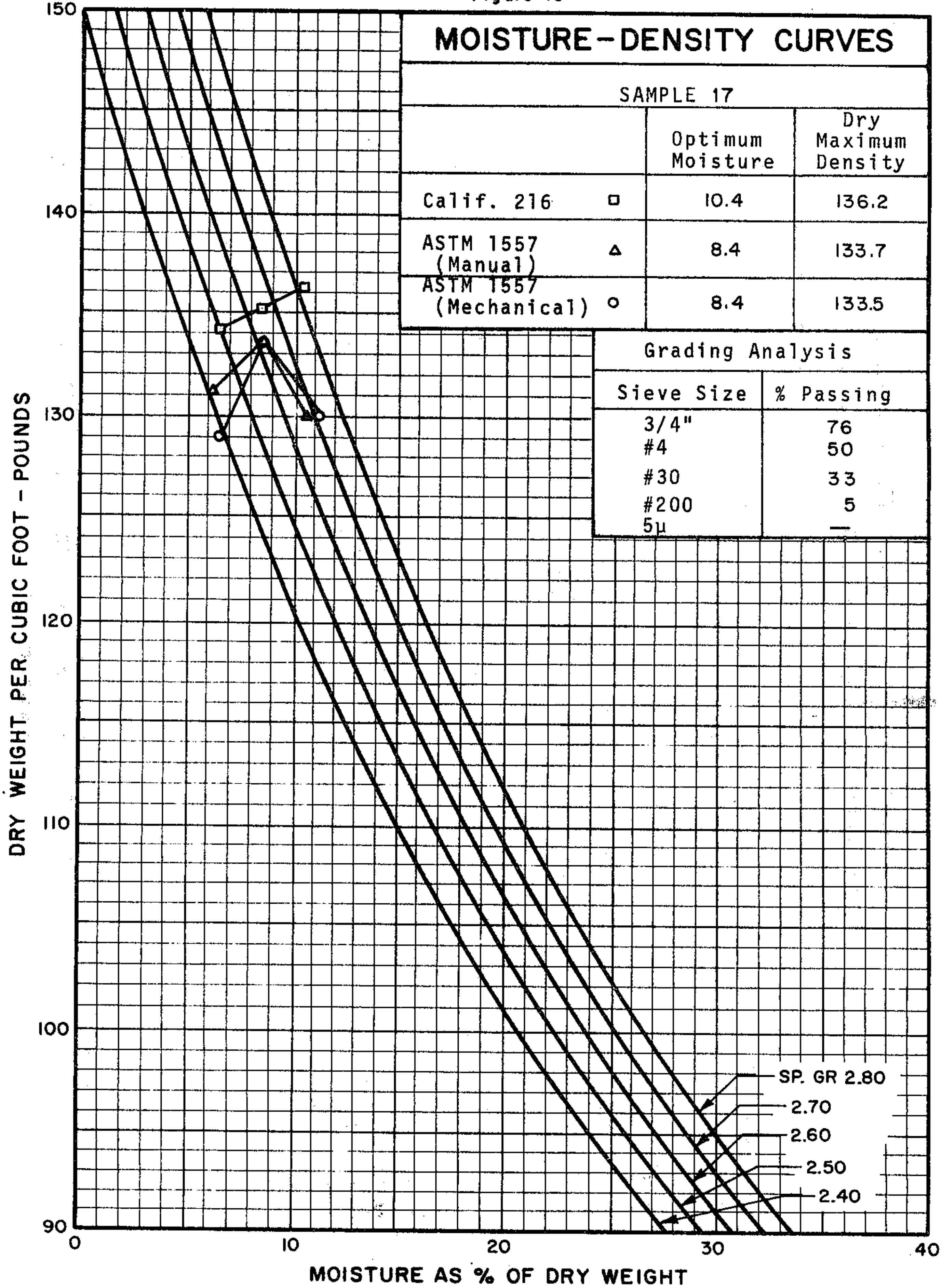

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Figure 20

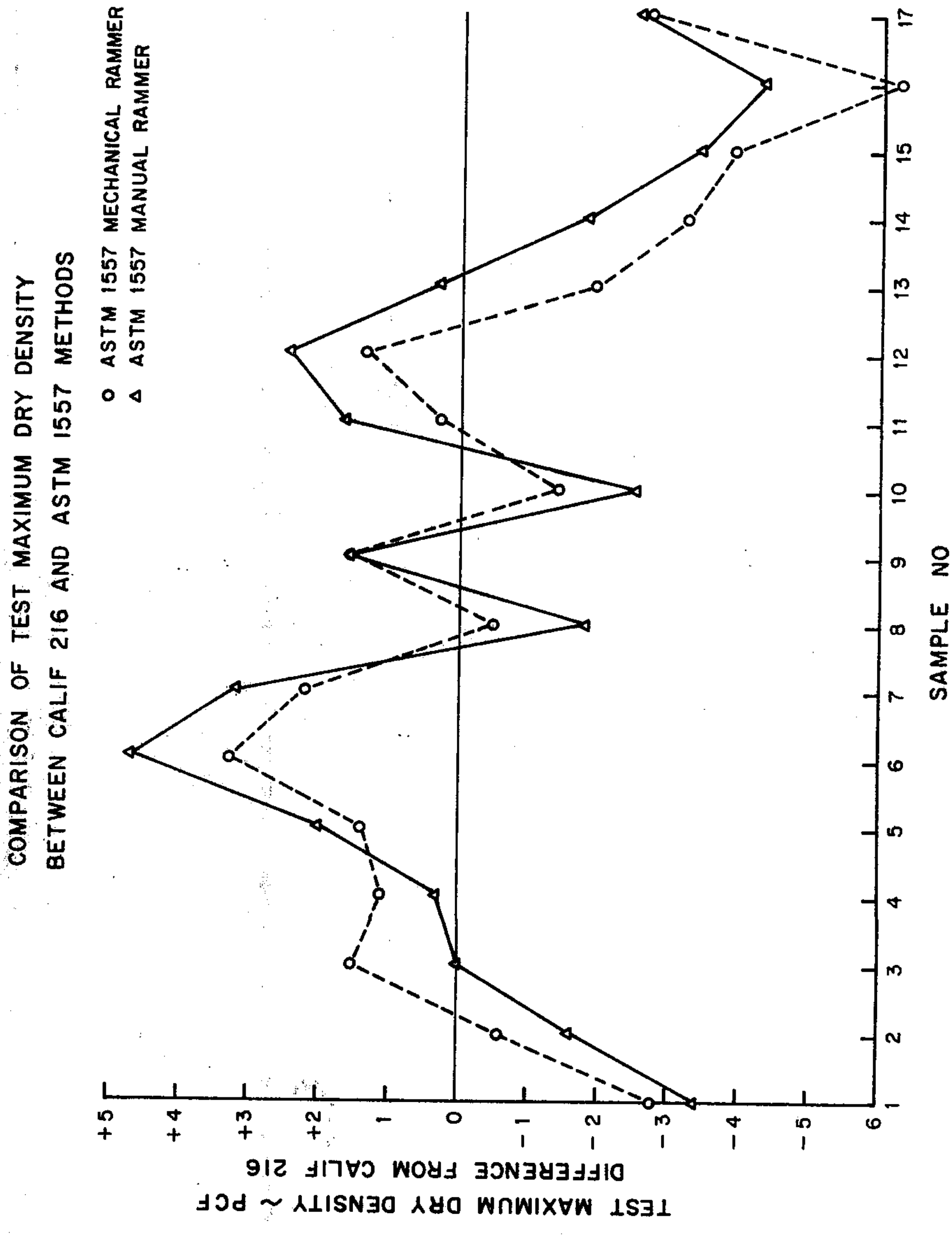

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Figure 21

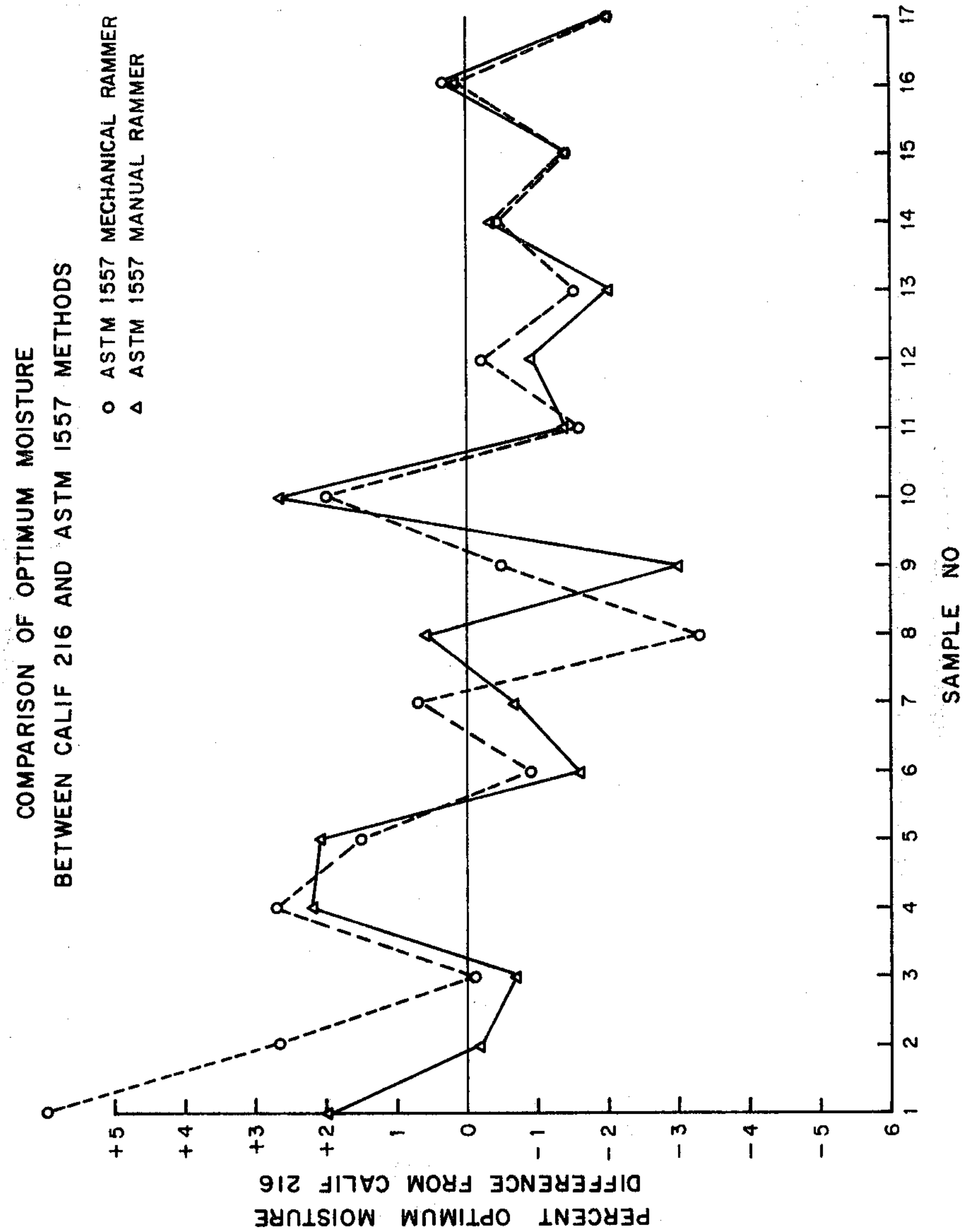

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Figure 22

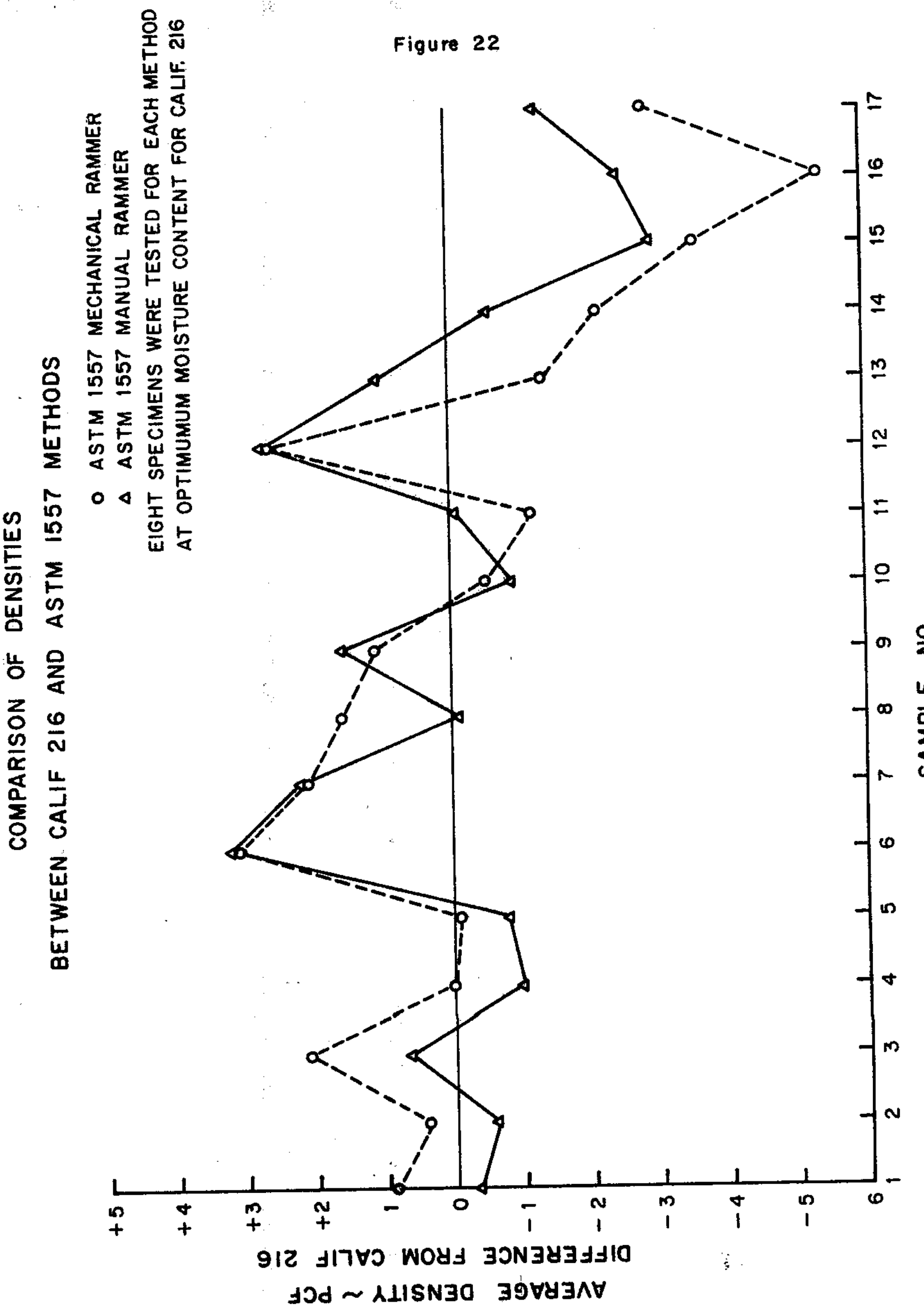

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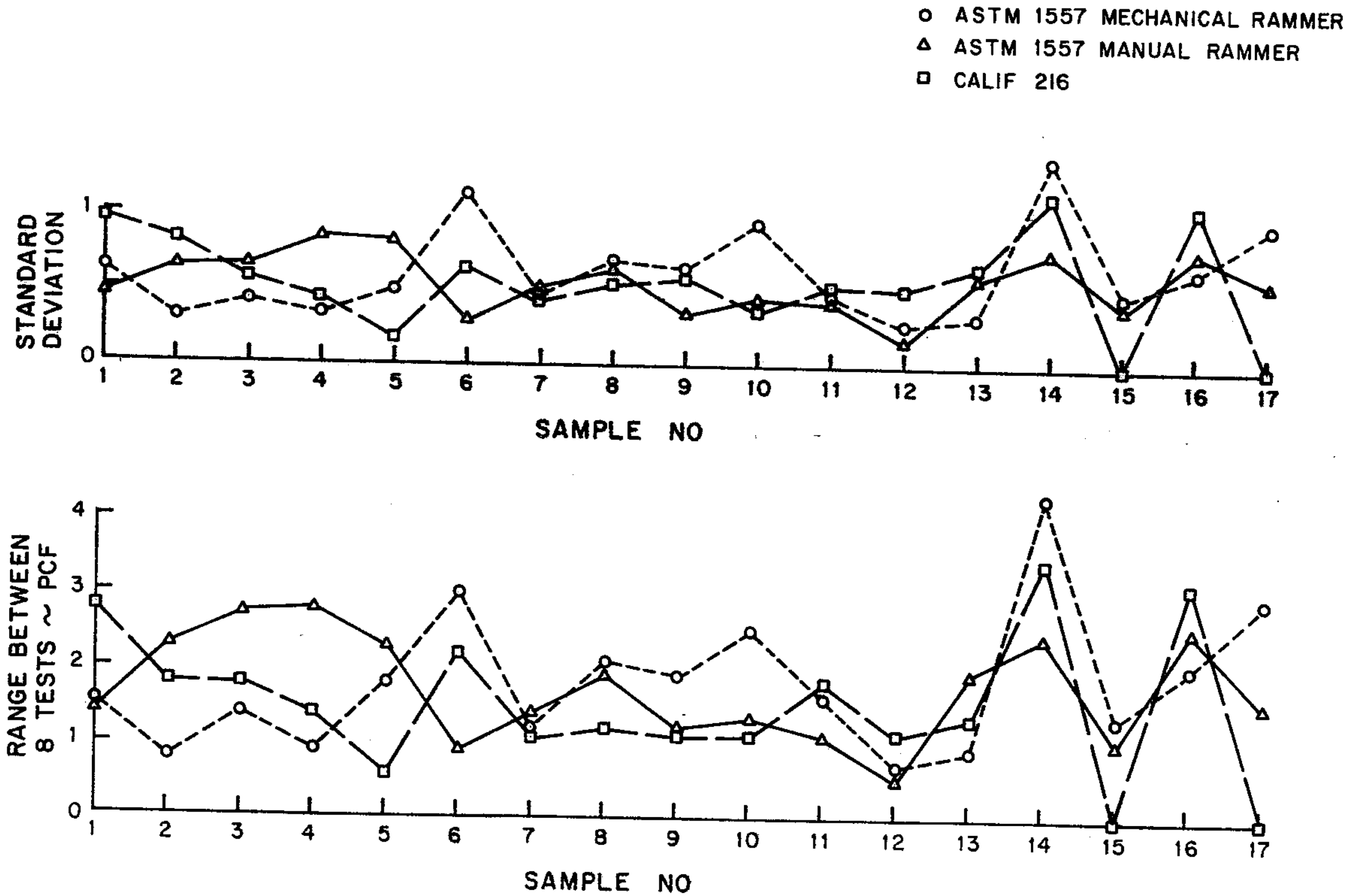
Figure 23

VARIATION OF REPLICATE TESTS

BY CALIF 216 AND ASTM 1557 METHODS



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APPENDICES

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APPENDIX A

SPECIFICATIONS FOR EXPERIMENTAL CALIFORNIA IMPACT COMPACTOR

General

This compactor shall be a hydraulic device for compacting soil and aggregate samples. Through action of a tamping foot, the compactor shall automatically apply a preset number of tamps per layer and automatically feed the sample into the mold in five layers. The tamping foot shall weigh 10 pounds and have a removable 2 inch diameter heat treated foot and adjustable free fall between 12 and 18 inches regardless of height of soil in the mold.

The compactor shall be specifically designed for use with Test Method No. Calif. 216 and shall be capable of fabricating test specimens to the requirements of this method. Copies of this test method will be made available to prospective bidders on request.

This compactor shall be floor mounted and self contained in not more than two units. All mechanisms shall be completely enclosed in suitable housings, using all-welded construction which will have such access openings as are necessary for the inspection, repair and maintenance of the contained machinery. The access openings shall be covered with panel doors equipped with piano hinges and quick acting knobs. The housing for this compactor shall be constructed of at least 14 gage steel. All electric motors and associated control equipment shall conform to NEMA standards.

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Automatic lubrication shall be provided where necessary and the lubricating system shall be so designed that it may be easily serviced by the purchaser.

Design of the compactor housing and location of all indicators and controls, as well as the configuration of the specimen fabrication shall reflect consideration of the human operator and the manner in which he functions as the user of the machine. The overall design will reflect the use of modern industrial standards in configuration and appearance.

The working table around the turntable shall be illuminated by indirect lighting and the table shall be at a height of 28 $\pm$ 1 inch. The tabletop shall be constructed of 1/4 inch thick steel.

Operational Parameters

Power shall be supplied with a 230 volt 60 cycle three phase electric motor of at least three horsepower. Provisions will be made which will permit easy adjustment to vary the number of stroke cycles per minute at least from 20 to 60.

The turntable shall be 7.5 inches $\pm$ 0.25 inches in diameter and shall be constructed to be capable of receiving and fastening securely a 3 inch diameter x 15 inch high mold. The turntable shall be constructed of steel, activated mechanically or by hydraulics and electronically timed to the tamper foot. It shall be supported by ball thrust bearings with a minimum outside diameter of 4.5 inches. Provisions shall be made so the turntable can be adapted to accommodate mold sizes up to a 6 inch diameter x 8 inch high mold.

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The turntable, at time of delivery, shall be adjusted to rotate at the rate of one complete rotation for each seven tamps of the foot. Provisions shall be made to permit adjustments between at least five to sixty tamps per one rotation of the turntable.

A six column Hecon or equivalent quality predetermining electromagnetic additive counter shall be provided to record accumulated tamps on the specimen. A manually operated off-on switch shall actuate the counter. This machine shall be capable of being stopped at any time without affecting the recorded tamps to the specimen.

The tamper foot shall be such that after completing a preset number of tamps, the tamper foot can be raised so that an additional layer of soil can be put into the mold. The tamper must then be able to be set on top of the soil so that a preset height of free fall is obtained automatically when the mechanical tamper is activated.

A stop-start switch will be so mounted so that easy access is obtainable. This switch will be able to override all preset operations.

Hydraulic System

The hydraulic reservoir shall have a minimum capacity of 20 gallons. The reservoir shall be of all steel construction.

The hydraulic pump shall be of the multiple piston type, variable displacement, with adjustable pressure compensator. The pump shall have a flow of at least five gallons per minute at 1800 rpm. The pump shall also have an operating pressure of at least 1000 psi.

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Impulses, if any, from pumps or motors, shall so overlap that there will be no perceptible pulsation which would affect the accuracy of the controls.

Flow control valves shall have a flow range of 0.02 to 6.0 gallons per minute.

The piston rods for the hydraulic cylinders shall be constructed of 100,000 psi minimum yield strength material and shall be hard chrome plated.

The piston rod wipers shall be a synthetic rubber lip type. The rod packings shall be synthetic rubber vee type, and a bronze rod bearing shall be used. A bronze piston support bearing shall also be used. The piston packing shall be synthetic rubber vee type.

The cylinder barrels shall be heavy walled microhoned steel, and shall have an operating pressure of at least 1500 psi minimum.

Solenoid valves shall be 24 volt DC. They shall be subplate mounted with minimum flow of three gallons per minute.

An easily replaceable ten micron filter shall be furnished and installed in an effective place in the hydraulic system.

Safety

All moving parts shall be properly encased so all hazards to the operator are eliminated in accordance with the applicable regulations of the California Division of Industrial Safety. The tamping foot must be positively locked in place when the operator is placing or removing the mold from the turntable.

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Sample Extractor

The compactor shall be provided with a horizontal hydraulic device to extrude the sample from the mold.

Control Panel

All functions on the instrument panel are to be engraved on a phenolic plastic laminate.

Electronic System

The use of contacts and relays shall be avoided to provide the utmost in reliability. The hydraulic or mechanical system is to be operated by solid state control.

Integrated circuit technology shall be used in connection with proven, reliable transistor circuit design which will be voltage stabilized and temperature compensated.

Plug-in glass epoxy circuit mountings shall be used which are ammune from vibration, mechanically sound, and easily replaced.

The following controls will be placed on the front control panel:

1. Mode Switch - Position 1: Tamper only. Position 2: Automatic Feeder cycle.

2. Drop Height Switch - Position 1: Adjustable from 4 inches to 12 inches. Position 2: Adjustable from 12 inches to 20 inches.

3. Feeder Control - Adjusts endless belt travel.

4. Turn Table Control - Adjusts rotational travel.

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5. <u>Counter 1</u> - A predetermining counter to indicate and control the number of tamps applied to specimen.

6. <u>Counter 2</u> - A predetermining counter to indicate and control the number of feed increments.

7. <u>Counter 3</u> - A predterminining counter to indicate and control the number of times counters 1 and 2 repeat their preset count.

8. <u>Stop Switch</u> - An override on all control modes.

9. <u>Start Switch</u> - Indicates start of all control modes.

10. <u>Feeder Switch</u> - A manual control for advancing the feeder belt.

11. <u>Power Switch</u> - A master switch to activate the electronic control system, electrical system and hydraulic unit.

Counters number 4 through 6 shall be predetermining, 6 column, additive type with electrical reset. "Hecon" or equivalent quality.

Switches number 7 through 10 shall be a rectangular display modular lighted pushbutton switch. "Honeywell series 2, type 2C", or equivalent quality.

<u>Height Measuring Device</u>

Attention is directed to Test Method No. Calif. 216 where a steel piston is placed in the mold and five final blows of the tamper dropping from 18 inches is used to level the specimen.

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The compactor shall have a height measuring device that measures the height of specimen over the steel piston. The height of specimens generally range between 10 and 12 inches.

Verification of Accuracy

After delivery and prior to final acceptance, the compactor will be verified by the California Department of Transportation, Transportation Laboratory, with an electronic load cell and chart recorder.

The capability of the compactor to reproduce similar time-load curves continuously while in operation will be evaluated. There will be no measurable deviation between time-load curves at an 18 inch free fall with a 10 pound foot. The total force shall be 15.0 pounds per blow $\pm$ 0.1 pound.

It shall be possible, with minimum effort, to stop rotation of the turntable to provide for calibration of this compactor.

Accessories

An automatic feeder assembly and a mold holder shall be furnished by the supplier and included in the bid price for the compactor.

The automatic feeder assembly shall be of the endless belt type activated by hydraulics and electronically timed to the tamper foot. The belt travel shall be infinitely variable from one-half to two inches per pulse. Feeder belt travel adjustment shall be located on the front control panel. The capacity of the feeder belt shall be at least 3000 grams. The length of the feeder capable of being charged with a sample of material at one time shall be at least 20 inches.

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The mold holder shall be capable of fastening securely a mold of 3-1/4 inches outside diameter by 15 inches high.

Delivery, Installation, and Service

The vendor shall be responsible for delivery of the compactor to the customer's dock at 5900 Folsom Boulevard, Sacramento, California. The vendor shall provide the services of a trained service machinist or technician to check installation and assembly and to instruct the customer's personnel in the machine's operation and care.

The compactor shall be delivered within 90 calendar days from the date the purchase order is received by the vendor.

The machine and all accessories shall be fully guaranteed against defects in materials and workmanship, such as might result in normal hard usage, for a period of at least one year from the date of acceptance. Necessary repairs (due to defects in materials and workmanship) shall be performed at the vendor's expense.

Complete instructions for maintanance and operation shall be delivered to the Department of Transportation prior to, or at the time of, delivery of the testing machine.

Manufacturer's representatives, who are capable of providing complete maintenance and repair services, at any time, shall maintain and staff permanent facilities within the State of California.

Vendor's Bid Proposal

The vendor's proposal shall comment on all the requirements of these specifications in detail and shall state "exception" to

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each requirement where exception is taken with a full explanation of each deviation or absence of a feature.

In addition, each bidder shall submit with and as a part of his proposal, an outline of the methods and materials he proposes to use, a sketch and outline of the features of the hydraulic system of the compactor, a sketch showing the appearance of the finished machine, and a sketch showing location and arrangement of all controls and instruments to be located on the front panel of the compactor. These outlines shall be general but in sufficient detail to explain such things as grades of steel to be used, types of heat treatments, control panel layout, etc.

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APPENDIX B

State of California
Department of Transportation
Transportation Laboratory

A PROPOSED METHOD FOR CALIBRATING COMPACTION TEST EQUIPMENT AND CERTIFYING TEST OPERATORS

SCOPE

The procedure for calibration of test equipment is described and outlined in this method. The equipment is used for determining the test maximum density of treated and untreated soils and aggregates. This method also outlines a procedure for certifying operators using the manual procedure.

Part 1 Method of Calibrating the Test Mold, Collar and Baseplate

A. Apparatus

1. A metal cylindrical mold, baseplate, collar and extraction device (Figures I, II, and III).

2. A mechanical and/or manual rammer.

3. Weighing scale of minimum 5 kilogram capacity, sensitive to 1 gram.

4. Pouring containers of 1 litre capacity.

5. Eye dropper.

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6. Unbreakable flat transparent nonpliable plate about 5 x 5 inches square (127 x 127 mm).

7. Water insoluble heavy weight grease.

8. Dial Indicator reading to 0.001 inch (0.25 mm) and stand to measure a mold 4-1/2 inch (114.3 mm) high. (Figure IV)

9. Scale to measure 18 inch (457.2 mm) length of rod.

10. Inside calipers or micrometer with at least 4-1/2 inch (104.3 mm) capacity graduated to 0.01 inch (0.25 mm).

B. Calibration Procedure

1. Examine joints and machined surfaces of mold, base plate and collar assembly to insure that they are smooth and will not show visible openings. Examine the hold down lug bolts and wing nuts and have repaired or replaced if necessary.

2. Examine the mold to see if it is out of round. Measure the inside diameter of the mold at 2 points 90 degrees to each other at the same distance from the end of the mold. The difference between two corresponding measurements at any point in the mold shall not exceed 0.032 inch (0.812 mm). Check the other measurements shown on Figure I or II. If the mold cannot be brought within these tolerances, discard the mold.

3. Place a thin bead of grease on the joint surfaces of the mold and base plate and assemble. The grease helps to seal the joint against water leakage.

4. Fill the water container with at least 2.2 pounds (1000 grams) of water and weigh with the eye dropper to the nearest gram.

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5. Grease the top of the mold and place the clear plate on the mold so that about a 1/2 inch (127 mm) opening is left. (Figure V) Carefully pour the weighed water into the sealed mold section. As the water level nears the top of the sealed section, complete the filling of the mold with the eye dropper.

6. Gently slide the clear plate across the opening while applying a slight downward pressure. This technique aids in determining whether the mold is completely filled with water. If while the plate is being slid across the surface of the opening, the viscous seal of the water shows an air bubble beginning, stop the plate. This shows that insufficient water is in the mold. Use the eye dropper to add water. Then resume sliding the plate across the opening. If the plate is pushing an excess of water in front as it is slid across the opening, carefully remove some water with the eye dropper. Be careful not to lose any water.

7. When the filling operation is successfully completed, weigh the remaining water to the nearest gram.

8. The difference between the initial and final weight of water is the volume in cubic centimeters of the mold. Temperature corrections are made according to the values shown on the following Table I.

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TABLE I

VOLUME OF WATER PER GRAM BASED ON TEMPERATURE*

Deg C	Deg F	Volume of Water, ml/g
12	53.6	1.00048
14	57.2	1.00073
16	60.8	1.00103
18	64.4	1.00138
20	68.0	1.00177
22	71.6	1.00221
24	75.2	1.00268
26	78.8	1.00320
28	82.4	1.00375
30	86.0	1.00435
32	89.6	1.00497

*Values other than shown may be obtained by referring to the Handbook of Chemistry and Physics, Chemical Rubber Publishing Company, Cleveland, Ohio.

Example: If the weight of water is 944 grams and the temperature is 86 degrees, the product of 944 and 1.00435 is 948 cc.

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9. If the average internal diameter, height and volume are not within the tolerances shown in Figure I or Figure II, the determined volume shall be used in computing densities, rather than the prescribed 1/30 cf (944 cc).

10. In some cases, adjustments to the mold assembly can be made by a machine shop so that the assembly will conform to the dimensions shown on Figures I, II, and III.

Note: The mold shall be calibrated at intervals not exceeding 500 moisture density tests or at least once a year, whichever occurs first.

Part 2 Method of Calibrating the Manual and Mechanical Compactor

A. Apparatus

1. Manual rammer.

2. Mechanical rammer.

3. Lead Deformation Apparatus (Figure VI).

4. Scale with a minimum 5,000 gram capacity sensitive to ± 1 gram.

5. Steel rule at least 12 inches long graduated to .01 inch.

B. Calibration Procedure

1. Manual rammer - A manually operated metal rammer having a 2.0 ± 0.005 inch (50.80 ± 0.13 mm) diameter circular face and weighing 10 ± 0.02 pounds (4.54 kg ± 0.01 kg). The rammer shall be equipped with a suitable guidesleeve to control the height of drop to a free fall of 18.0 ± 1/16 inch (45.72 ± 0.16 cm) above the elevation of the sample. The guidesleeve shall have at least 4 vent holes not smaller than 3/8 inch (9.5 mm) spaced

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90 degrees apart and 3/4 inch (19.0 mm) from each end and shall provide sufficient clearance that free fall of the rammer shaft and head will not be restricted.

2. Mechanical rammer - A mechanically operated metal rammer having a 2.0 ± 0.005 inch (50.80 ± 0.13 mm) diameter circular face and weighing 10 ± 0.02 pounds (4.54 kg ± 0.01 kg). The rammer shall be equipped with a suitable guidesleeve to control the height of drop to a free fall of 18.0 ± 1/16 inch (45.72 ± 0.16 cm) above the elevation of the sample and providing uniform distribution of such drops on the sample. There shall be 0.10 ± 0.03 inch (2.5 ± 0.8 mm) clearance between the rammer and the smallest diameter of the mold. The manufactured weight of the free falling rammer assembly shall be 10 ± 0.02 pounds (4.54 ± 0.01 kg).

3. Lead deformation measurements by the manual rammer.

a. Select a set of lead cylinders from the same lot or shipment. A minimum of five is needed for the calibration of a mechanical compactor. Remove any burrs from the ends of the lead cylinders using a fine grade of emery cloth.

NOTE 1 - Deformation of the lead cylinders is affected by changes in temperature. Precautions need to be taken to maintain the cylinders at a constant temperature during the calibration of a mechanical compactor including the securing of the values for the manual method.

b. Assemble the lead deformation apparatus with a lead cylinder in place as shown in Figures VI and VII.

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c. Place the assembled deformation apparatus on the base of the dial comparator with the top center of the striking pin directly under the tip of the dial stem. This places the dial stem on top of the 1/4 inch (6.4 mm) steel ball. Rotate the striking pin rapidly several turns in one direction while rotating the guide sleeve rapidly several turns in the opposite direction. Read and record the dial reading.

d. Place the base plate of the compaction mold on the 200 pound (90.7 kg) cylinder or cube of concrete; place the deformation apparatus on the base plate; place the guide sleeve pedestal in position on the base plate, mount the rammer and guide sleeve on the guide sleeve pedestal, and apply one drop of the manual rammer.

e. Return the deformation apparatus to the dial comparator and record the dial reading. The difference between the dial readings secured in 3c and in this step is the deformation value.

f. Repeat steps 3a through 3e using an unused lead cylinder for each determination, until five deformation values are secured that do not vary more than 2% from the average. The deformation value for the manual method shall be taken as this average value.

4. Lead deformation measurements by the mechanical rammer.

a. Clean and adjust the mechanical compactor in accordance with the manufacturer's instructions. Operate the compactor for a period of time to cause friction in the parts to become constant, allowing the rammer to fall on soil or other soft material. Place the deformation apparatus under the mechanical rammer and obtain deformation values as outlined in the preceding section 3.

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5. The average deformation value of the mechanical rammer must be within 1.5 percent of the manual rammer. If it is not, the mechanical rammer guides should be corrected so that a free fall condition is attained.

NOTE: The mechanical rammer shall be calibrated at intervals not exceeding 500 moisture density tests or at least once a year, whichever occurs first.

Part 3 Method of Qualifying Test Operators

A. Apparatus

1. Mechanical and manual compactors.

2. A clay and a silty clay material.

B. A sample, approximately 20 kg, of each of the two materials to be used for operator certification shall be shipped in moisture proof containers to the Transportation Laboratory in Sacramento. A series of tests to determine the maximum density and optimum moisture shall be performed on each of the two samples using the mechanical method and following the procedure outlined in the proposed test method covered in Appendix III. The results of the mechanical method tests shall be obtained from the Transportation Laboratory prior to the test operator certification.

C. The test operator shall perform a series of tests to determine maximum density and optimum moisture on each of the two materials using the manual method and following the procedure outlined in the proposed test method covered in Appendix III.

D. The test maximum density by the manual method shall not vary from the mechanical method by more than ± 2.0 percent. The optimum

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moisture by the manual method shall not vary from the mechanical method by more than ± 0.5 percent. If the operator does not meet these criteria using the two type soils, the person is not certified to perform the test using the manual rammer. However, certification can be attained through additional training and testing.

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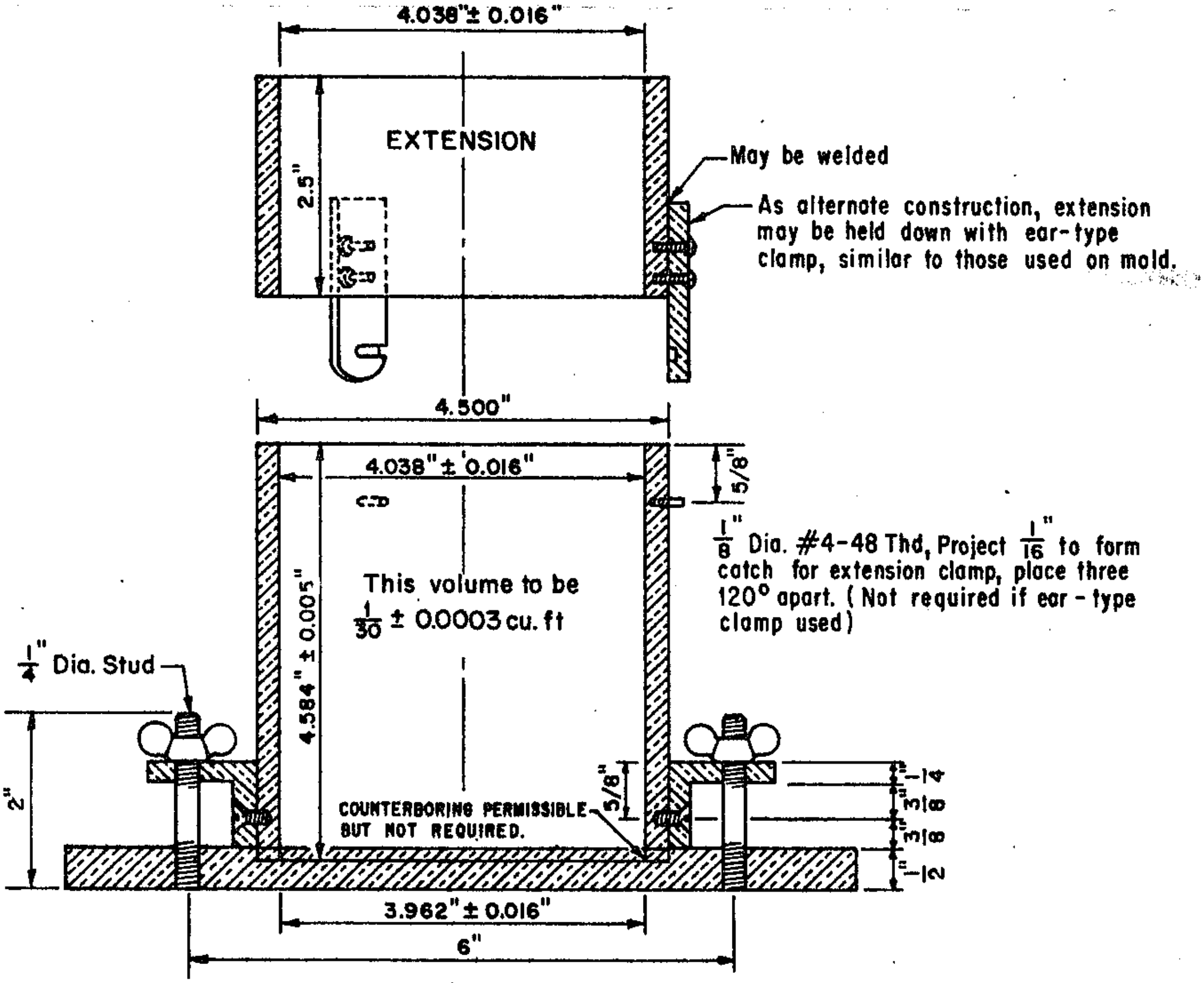

METRIC EQUIVALENTS					
in	mm	in	mm	in	mm
0.005	0.13	3/8	9.53	3.962	100.63
0.016	0.41	1/2	12.70	4.000	101.60
0.026	0.66	5/8	15.88	4.038	102.57
1/16	1.59	3/4	19.05	4.500	114.30
1/8	3.18	2	50.80	4.584	116.43
1/4	6.35	2 1/2	63.50	6.000	152.40

cu. ft.	cu. cm.
1/30	9.44
0.0003	8

Fig. I TAPERED MOLD

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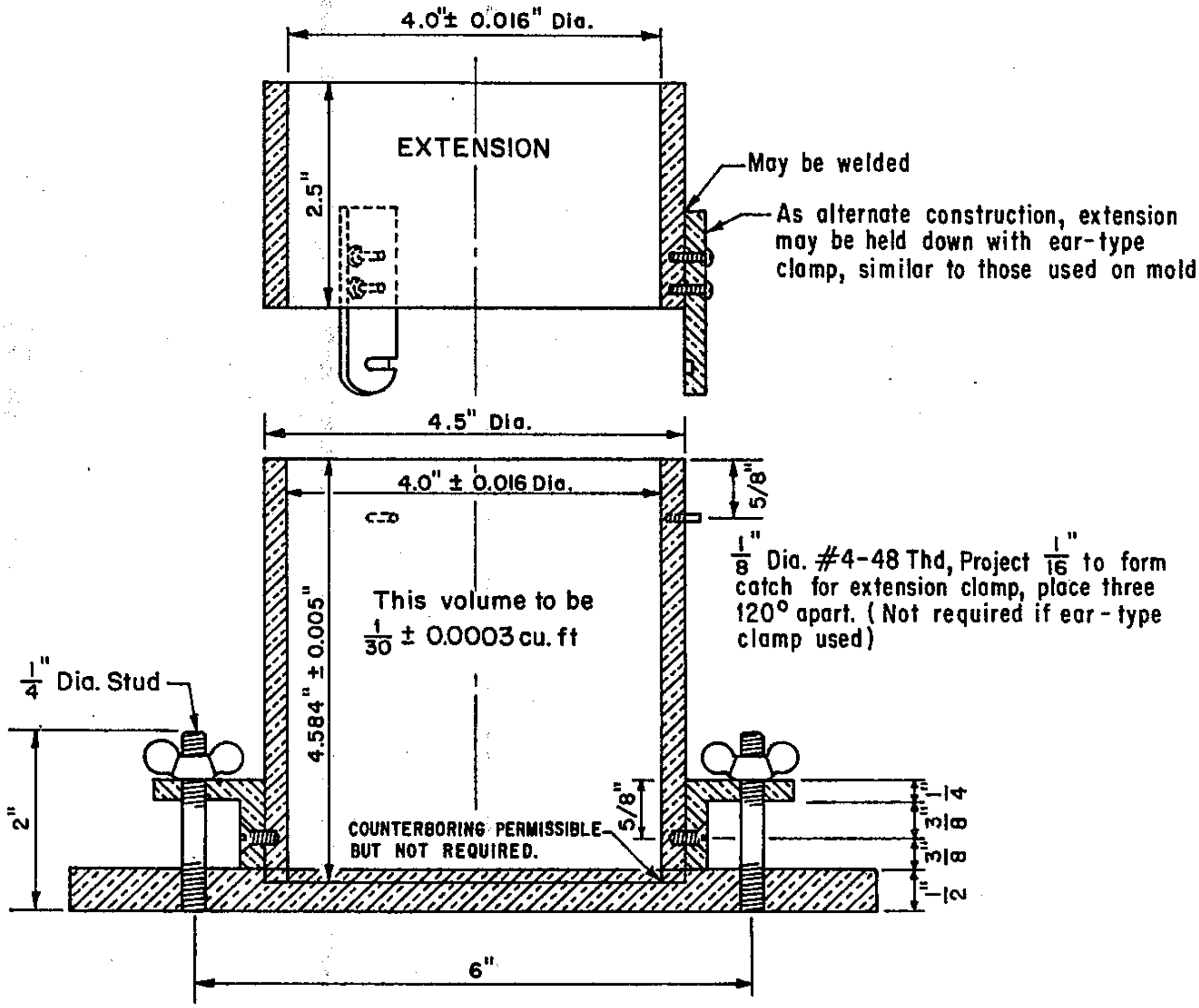
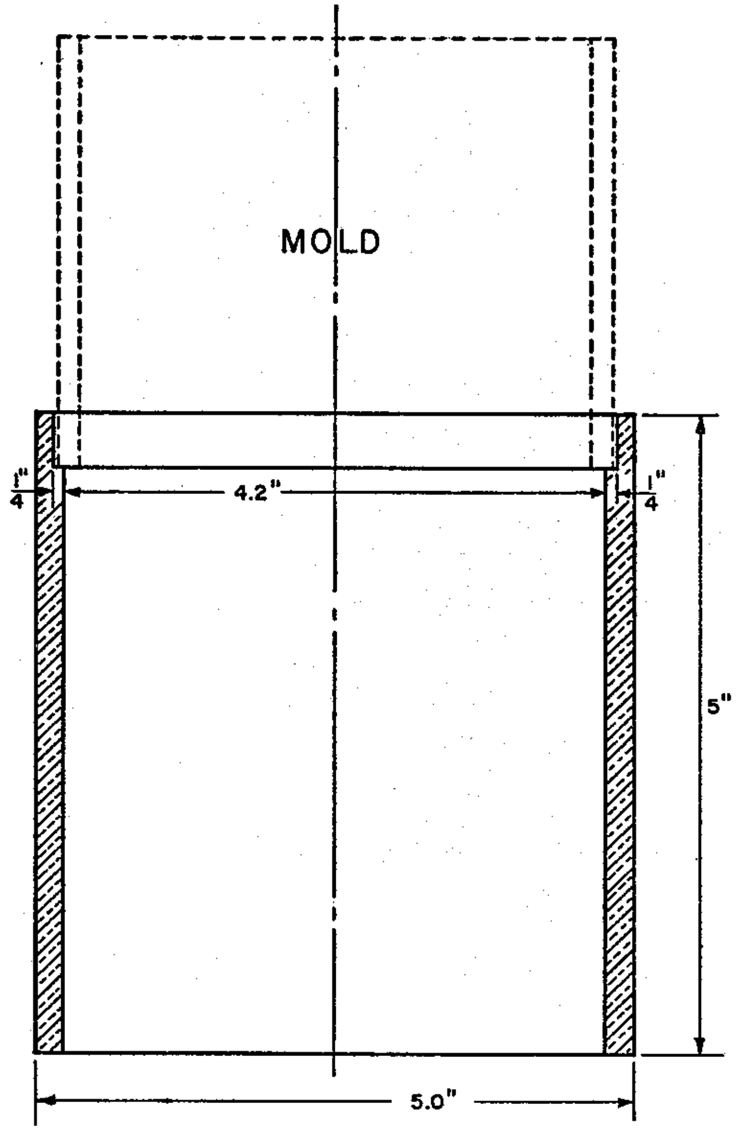


4.0"± 0.016" Dia.
EXTENSION
2.5"
May be welded
As alternate construction, extension may be held down with ear-type clamp, similar to those used on mold.
4.5" Dia.
4.0" ± 0.016 Dia.
5/8"
1/8" Dia. #4-48 Thd, Project 1/16" to form catch for extension clamp, place three 120° apart. (Not required if ear-type clamp used)
This volume to be 1/30 ± 0.0003 cu. ft
4.584" ± 0.005"
1/4" Dia. Stud
2"
5/8"
COUNTERBORING PERMISSIBLE BUT NOT REQUIRED.
1/4"
3/8"
3/8"
1/2"
6"



METRIC EQUIVALENTS					
in	mm	in	mm	in	mm
0.005	0.13	3/8	9.53	3.962	100.63
0.016	0.41	1/2	12.70	4.000	101.60
0.026	0.66	5/8	15.88	4.038	102.57
1/16	1.59	3/4	19.05	4.500	114.30
1/8	3.18	2	50.80	4.584	116.43
1/4	6.35	2 1/2	63.50	6.000	152.40

cu. ft.	cu. cm.
1/30	9.44
0.0003	8

Fig. III EXTRACTION DEVICE

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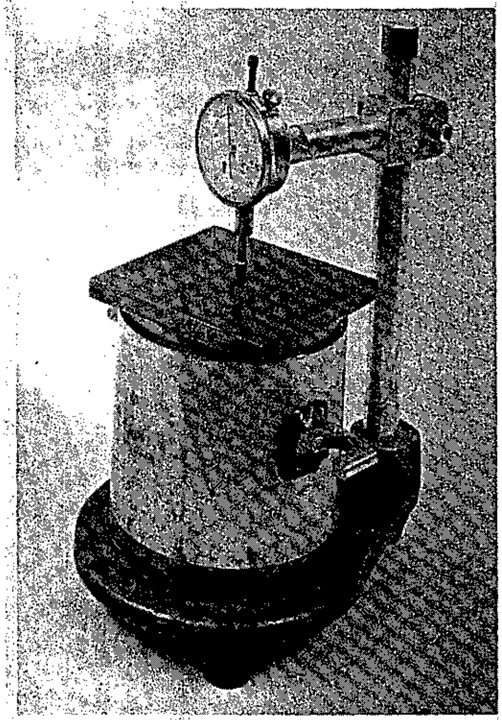

Figure IV

Measuring Device

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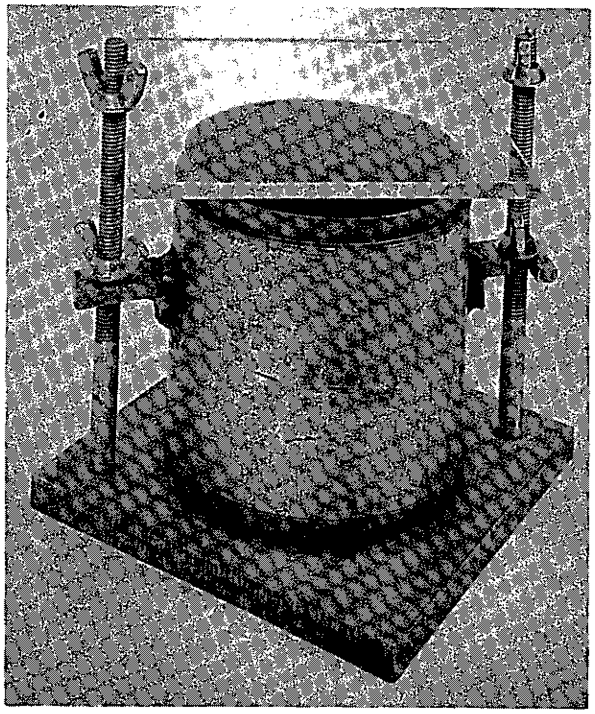

Figure V

Volumetric Calibration

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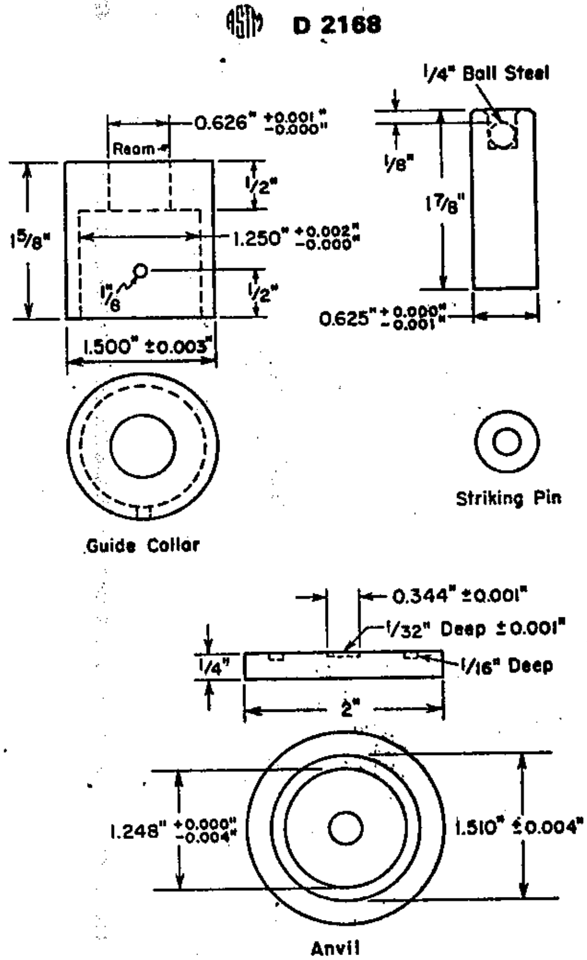

Figure VI

Lead Deformation Apparatus Details
(From ASTM D2168)

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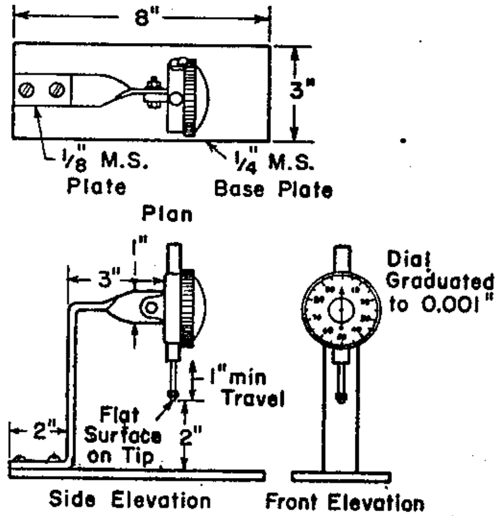
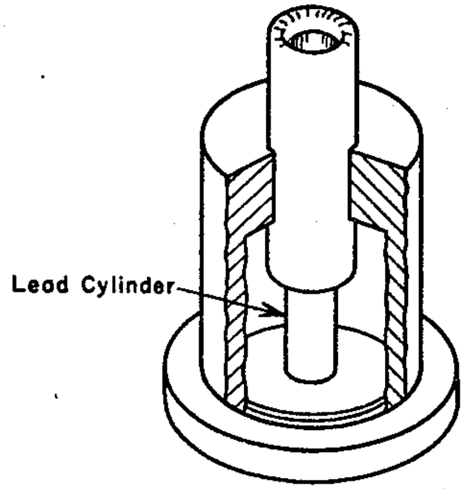
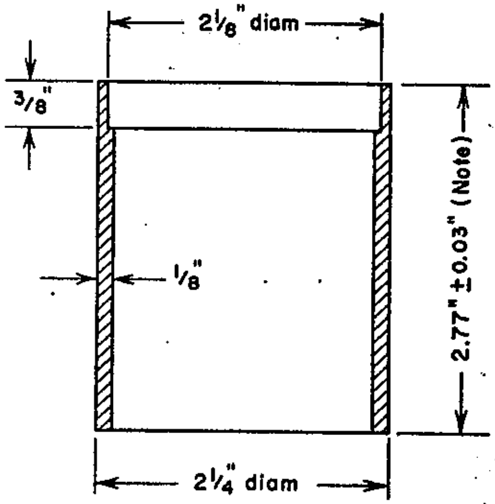


Dial Comparator.



Lead Deformation Apparatus Assembly.



NOTE—This dimension must be equal to the height of the lead deformation apparatus when assembled with the lead cylinder in place.

Guide Sleeve Pedestal.

Figure VII

Lead Deformation Apparatus Details
(From ASTM D2168)

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Impact Compaction Test Mold
Calibration Record

Mold No. __________ Date__________ District__________ By__________

Collar Ht. Spec 2.5 ± 0.1 in. (63.5 ± 2.54 mm) ______________

Collar Dia. Spec. 4.0 ± 0.016 in. (101.60 ± 0.41 mm) __________

Straight Wall Mold

Ht. Spec. 4.584 ± 0.005 in. (116.43 ± 0.127 mm) __________
Dia. Spec. 4.0 ± 0.016 in. (101.60 ± 0.41 mm) ____________

Tapered Wall Mold

Ht. Spec. 4.584 ± 0.005 in. (116.43 ± 0.127 mm) __________
Top Dia. Spec. 4.038 ± 0.016 in. (102.57 ± 0.41 mm) ________
Bot. Dia. Spec. 3.962 ± 0.016 in. (100.63 ± 0.41 mm) _______

Cubic centimeters of water to fill mold.

		Trial 2	Trial 2	Trial 3
1.	Initial wt. of water (grams)	______	______	______
2.	Remaining wt. of water (grams)	______	______	______
3.	Wt. of water to fill mold (1-3)(gm)	______	______	______

4. Average wt. of water $\frac{\text{Trial } 1+2+3}{3}$ (grams) ______________
5. Temperature of water__________ Correction factor ____________
6. Correction for temperature 4 x factor (volume cc) ____________
7. Volume of mold spec. 1/30 ± 0.0003 cf (944 ± 0.85 cc)

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Impact Compaction Rammer
Calibration Record

Rammer No.__________ Date__________ District______ By__________

1. Rammer Wt. Spec. 10 ± 0.02 lb (4536 ± 9 gram)__________

2. Rammer face Spec. 2.0 ± 0.005 in. (50.8 ± 0.13 mm) diameter circular face __________

3. Height of Drop Spec. 18.0 ± 1/16 in. (457.2 ± 1.6 mm) ______

4. Manual Rammer 4 vent holes in guide _ 3/8 in. (9.5 mm) spaced 90° apart and 3/4 in. (19.1 mm from each end __________

5. Mechanical Rammer Spec. 0.1 ± 0.03 in. (2.54 ± 0.76 mm) clearance between rammer and smallest diameter of mold.

6. Lead Deformation Tests

	Manual Rammer		Mechanical Rammer	
	Before Drop	After Drop	Before Drop	After Drop
1.	______	______	______	______
2.	______	______	______	______
3.	______	______	______	______
4.	______	______	______	______
5.	______	______	______	______
	______	______	______	______
	______	______	______	______
Difference	______		______	

Note: Each measurement in a set of 5 must be within 2% of the average of 5. Repeat tests until 5 meet this criteria.

The average difference between the manual and mechanical rammer shall be less than 1.5 percent of the manual rammer.

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APPENDIX C, Part 1

State of California
Department of Transportation
Transportation Laboratory

A PROPOSED METHOD OF TEST FOR DETERMINING LABORATORY COMPACTED TEST MAXIMUM WET DENSITY AND PERCENT RELATIVE COMPACTION USING A 1/30 FT.^{3} (944CC) MOLD

SCOPE

Relative compaction in this method is defined as the ratio of the inplace wet density of a treated or untreated soil or aggregate to the wet test maximum value of the same soil or aggregate when compacted by the procedure outlined in this method. The principal use of this method is for the compaction control of earthwork construction. The inplace wet density is determined by Test Method No. Calif. 216 or 231.

Part 1. Apparatus and Sampling

A. Apparatus

1. A metal cylindrical mold with detachable collar and base plate conforming to Figure I or II. The mold may be of the "split" type consisting of two half-round sections which can be securely locked in place to form a cylinder as described in Figures I or II. The mold, collar assembly and base plate shall fasten securely together in a manner which may vary from Figures I or II as long as they are functionally equivalent.

2. A sample extraction device conforming to Figure III.

3. A concrete block or an equally rigid body weighing not less than 200 lbs (90.7 kg).

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4. A manually operated metal rammer having a 2.0 ± 0.005 in. (50.80 ± 0.13 mm) diameter circular face and weighing 10 ± 0.02 lb (4.54 kg ± 0.01 kg). The rammer shall be equipped with a suitable guidesleeve to control the height of drop to a free fall of 18.0 ± 1/16 in. (45.72 ± 0.16 cm) above the elevation of the sample. The guidesleeve shall have at least 4 vent holes not smaller than 3/8 in. (9.5 mm) spaced 90 degrees apart and 3/4 in. (19.0 mm) from each end and shall provide sufficient clearance that free fall of the rammer shaft and head will not be restricted.

5. A mechanical rammer may be used in lieu of the manual rammer. The mechanically operated device shall be capable of compacting specimens by means of guided free fall drops of a metal rammer face from 18.0 ± 1/16 in. (45.72 ± 0.16 cm) above the sample surface elevation and providing uniform distribution of such drops on that surface. There shall be 0.10 ± 0.03 in. (2.5 ± 0.8 mm) clearance between the rammer and the smallest diameter of the mold. The manufactured weight of the free falling rammer shall be 10 ± 0.02 lb (4.54 ± 0.01 kg) and it shall have a circular face 2.0 ± 0.005 in. (50.80 ± 0.13 mm) in diameter.

6. A balance or scale of at least 3 Kg capacity sensitive to 1 gram.

7. A 2 in. (50.8 mm), 3/4 in. (19.1 mm) and No. 4 (4.75 mm) sieves.

8. A steel straightedge of any convenient length but not less than 10 in. (25.4 cm). The scraping edge shall be beveled and have a straightedge tolerance of ± 0.005 in. (± 0.13 mm).

9. Miscellaneous items such as mixing bowls, spoons, and a graduate.

The calibration of the mold assembly and tamper is covered in Test Method No. Calif. ___ .

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B. Bulk Sample

1. Obtain a bulk sample of material weighing at least 10 Kg at the site of the inplace density test. If Test Method No. Calif. 231 is being utilized for inplace density determinations, obtain an equal amount of material from each test site to form a bulk sample weighing at least 10 Kg.

2. <u>For this wet weight method of test, it is essential that the bulk sample be preserved at the same moisture as prevailed at the time of the inplace test</u>. Use only tightly covered metal containers and protect from high temperatures.

Part 2 Method of Test Sample Preparation

A. Bulk Sample Preparation

1. It is of the utmost importance that moisture losses be kept to a minimum by keeping the material in covered containers except when proportioning, mixing or compacting specimens.

2. Discard any rock retained on the 2 inch (50.8 mm) sieve. Then separate the bulk sample on the 3/4 inch (19.1 mm) sieve and compute the percent retained on the 3/4 inch (19.1 mm) sieve. If the amount retained on the 3/4 inch (19.1 mm) sieve is less than 10 percent by total weight of the sample, discard any retained 3/4 inch (19.1 mm) material and proceed with Part B. If the amount retained on the 3/4 inch (19.1 mm) is 10 percent or more, proceed with Part C.

B. For Less than 10 Percent Retained on the 3/4 inch Material.

1. Thoroughly mix the remaining sample and divide a portion of the material into an initial trial representative test specimen

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sufficient in amount to form a specimen slightly over the top of the mold, but not exceeding 1/4 inch (6.35 mm) when compacted as specified in the following Part 3. The maximum height requirement shall apply only to the initial specimen.

The correct weight for the initial test specimen will depend on the material type and moisture content.

2. Record the actual weight of the initial batched test specimen on lines I and J as illustrated on the example report on Figures IV and V.

C. For Materials with 10 percent or More Retained on the 3/4 inch (19.1 mm) Sieve.

1. Replace the material passing the 2 inch (50.8 mm) sieve and retained on the 3/4 inch (19.1 mm) sieve with an equal weight of material passing the 3/4 inch (19.1 mm) sieve and retained on the No. 4 (4.76 mm) sieve. The material replacing the discarded over-sized material should not have been used for prior tests. The correct weight for each specimen depends on the soil type and moisture content.

Example for a 1700 gram specimen.

Sieve Size	Grading Percent Passing	Grading Percent Retained	1700 gram Test Specimen Batch Weight	
2" (50.8 mm)	100			
3/4" (19.1 mm)	78	100 - 78 = 22	3/4" x No. 4 (.22+.22)x1700 =	748
No. 4 (4.76 mm)	56	78 - 56 = 22	Passing No. 4 .56 x 1700 =	952
			Total	1700

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2. Proportion an initial trial representative test specimen as outlined above. The batched specimen should be sufficient in amount to form a compacted specimen slightly over the top of the mold, but not exceeding 1/4 inch (6.4 mm) when compacted as specified in Part III. The maximum height requirement shall apply only to the initial specimen.

The correct weight for the test specimen will depend on the soil type and moisture content.

3. It is of the utmost importance that moisture losses be kept to a minimum by keeping specimens in individual covered containers except when proportioning, mixing or compacting specimens.

4. Record the actual weight of the initial trial batched test specimen as illustrated on the example report on Figure IV.

Part 3. Method of Test Specimen Compaction

A. SCOPE

1. Optimum moisture is defined as the water content of the compacted specimen with the highest wet maximum density even though the actual moisture content is unknown at the time of fabrication.

2. The object is to have one test specimen at optimum, a second slightly over and a third slightly under optimum. There should be approximately a 2 percent moisture increment between specimens. There may be cases where more than 3 specimens are needed.

3. The initial test specimen prepared as outlined in the foregoing Part 2 is generally compacted at the inplace field moisture content.

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4. Divide the initial test specimen prepared as outlined in the foregoing Part 2 into five approximately equal portions by weight or volume measurements. Place one portion in the assembled mold with extension collar and base plate and compact it with 25 blows of the tamper dropping free from a height of 18 in. (457.2 mm) above the surface of the material in the mold. Repeat this operation for each of the remaining four portions.

During compaction, the mold shall rest on a firm or rigid foundation, such as provided by a cube of concrete weighing not less than 200 lb (90.7 Kg).

7. In compacting the specimen care shall be taken to avoid rebound of the rammer from the top end of the guidesleeve. At least 35 seconds shall be required to apply the 25 blows and they shall be applied at a uniform rate.

6. Following compaction, remove the extension collar and carefully trim the compacted soil even with the top of the mold with a steel straightedge. Holes left in the specimen during this operation will be filled with smaller size material. Weigh and record the final test specimen weight as illustrated on Figures IV and V.

7. Place the large end of the tapered mold on the sample extruder and tap the specimen on the small end of the tapered mold to remove the specimen.

8. If the initial compacted specimen is within the limits outlined in Part 2-B1 and C1, batch 2 or more representative test specimens identical in weight to the initial specimen. If the initial specimen is not within the limits, repeat the procedure beginning with Part 2-B1 or C1.

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9. If the initial test specimen appears drier than optimum, mix additional water into each of the remaining specimens. If it appears to be wetter than optimum, reduce the moisture content by aeration. Oven drying at a temperature not exceeding 140°F (60°C) is permitted but do not dry until remixing with water is required. Air drying is the preferred method. In some cases, it may be necessary to add water to one specimen while the second may require drying. Record the water added or subtracted as illustrated on Figures IV and V.

10. The base plate of the test mold normally shows indications of dampness when a soil is compacted at test optimum moisture content. Free water on the plate definitely indicates excessive moisture content. A dry dusty plate indicates a deficiency of water.

11. Regardless of the soil type or particle sizes involved, fresh soil (not soil from previously compacted specimens) must be used in the compaction of each test specimen.

12. The calculations to determine the test maximum value are covered in Part 4 of this procedure.

13. Where dry densities are required, determine moisture contents in accordance with Test Method No. Calif. 226 and perform the necessary calculations.

Note: The wing nuts used in the mold assembly should be finger tightened. The purpose of a wrench is to release the wing nuts when locked by expansive soils. The use of the sample extruder, the tapered mold and lightly oiling the mold helps to remove the compacted soil specimen from the mold.

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Part 4 Determining Percent Relative Compaction

A. Calculate test specimen wet weight by the following equation:

$$T_m = \frac{FS}{943.9B} \qquad (1)$$

T_m = Test specimen maximum wet density in gms/cc
F = Final test specimen weight after trimming
S = Initial batched specimen weight
B = Initial batch specimen weight adjusted for added or subtracted water.
943.9 Cubic centimeters = the volume of the cylindrical test mold.

Example: Assume

F = 2040 grams (final specimen weight)
S = 2050 grams (initial batch weight)
B = 2150 grams (initial batch weight + 100 grams water)

$$T_m = \frac{2040 \times 2050}{943.9 \times 2150} = 2.06 \text{ g/cc}$$

"T_m" values for most soils are shown on Table I.

B. Calculation of Percent Relative Compaction

$$RC = \frac{D_w}{T_m} \times 100$$

RC = Percent Relative Compaction
D_w = Inplace wet density
T_m = Laboratory Specimen with highest wet maximum density as determined by this method.

Computations are carried to the nearest 0.1 percent.

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For reporting and for specification compliance purposes, show the percent relative compaction as a whole number. If the computed value ends in a number with a fractional portion 0.5 percent or greater, report as the next higher whole number. If the computed value is less than 0.5 percent, report without changing the whole number.

Example:

D_w = 2.08 grams/cubic centimeter
T_m = 2.16 grams/cubic centimeter

$$RC = \frac{2.08}{2.16} \times 100 = 96.3$$

Report RC 96%

C. Moisture Content

1. The moisture content of the compacted test specimen with the highest wet density is the optimum moisture. The moisture content of the specimen compacted without any moisture adjustment represents the inplace moisture content of the soil. If either moisture contents are needed, the determination is made in accordance with Test Method No. Calif. 226.

2. Dry weight of material is needed for such things as calculating Aggregate Base Pay Quantities and earthwork swell or shrinkage factors.

D. Moisture Density Curve

A moisture density curve may be formed by plotting the wet density versus change in grams of water added or subtracted in adjusting the moisture contents of the test samples. A sample curve is shown on Figure IV.

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The highest point on the curve represents the maximum wet density, in this instance 2.19 at +50 grams of water. No portions of the curve shall be drawn higher than the maximum test wet specimen density recorded.

E. Simplifications For Construction Control

Construction control by wet weight methods may be expedited. If the relative compaction based on any test specimen is below the specified minimum, it may be reported that the area under test has failed to meet specifications. It is not necessary to fabricate additional test specimens for the reason that if a higher wet test maximum value was reached with subsequent test specimens, the relative compaction based on this higher value would be lower than that indicated by the single specimen.

When the relative compaction indicated by a single test specimen is more than the minimum specified, additional specimens are necessary to be certain that any increase in the wet test maximum density attained with the subsequent specimens do not lower the relative compaction value to below the specified minimum.

References

Test Method No. Calif. 226

Test Method No. Calif. 231

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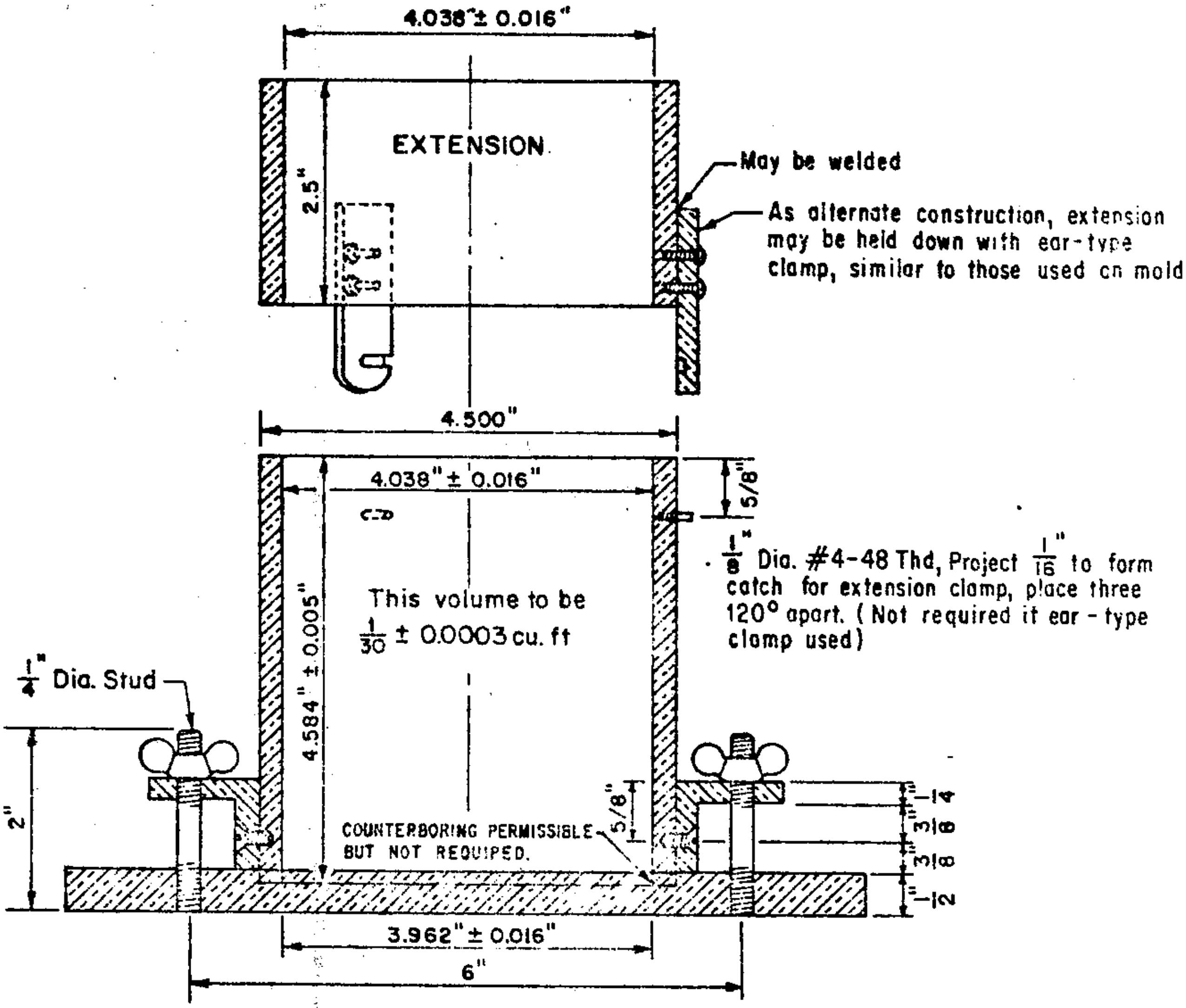

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0.026	0.66	5/8	15.88	4.038	102.57
1/16	1.59	3/4	19.05	4.500	114.30
1/8	3.18	2	50.80	4.584	116.43
1/4	6.35	2 1/2	63.50	6.000	152.40

cu. ft.	cu. cm.
1/30	9.44
0.0003	8

Fig. I TAPERED MOLD

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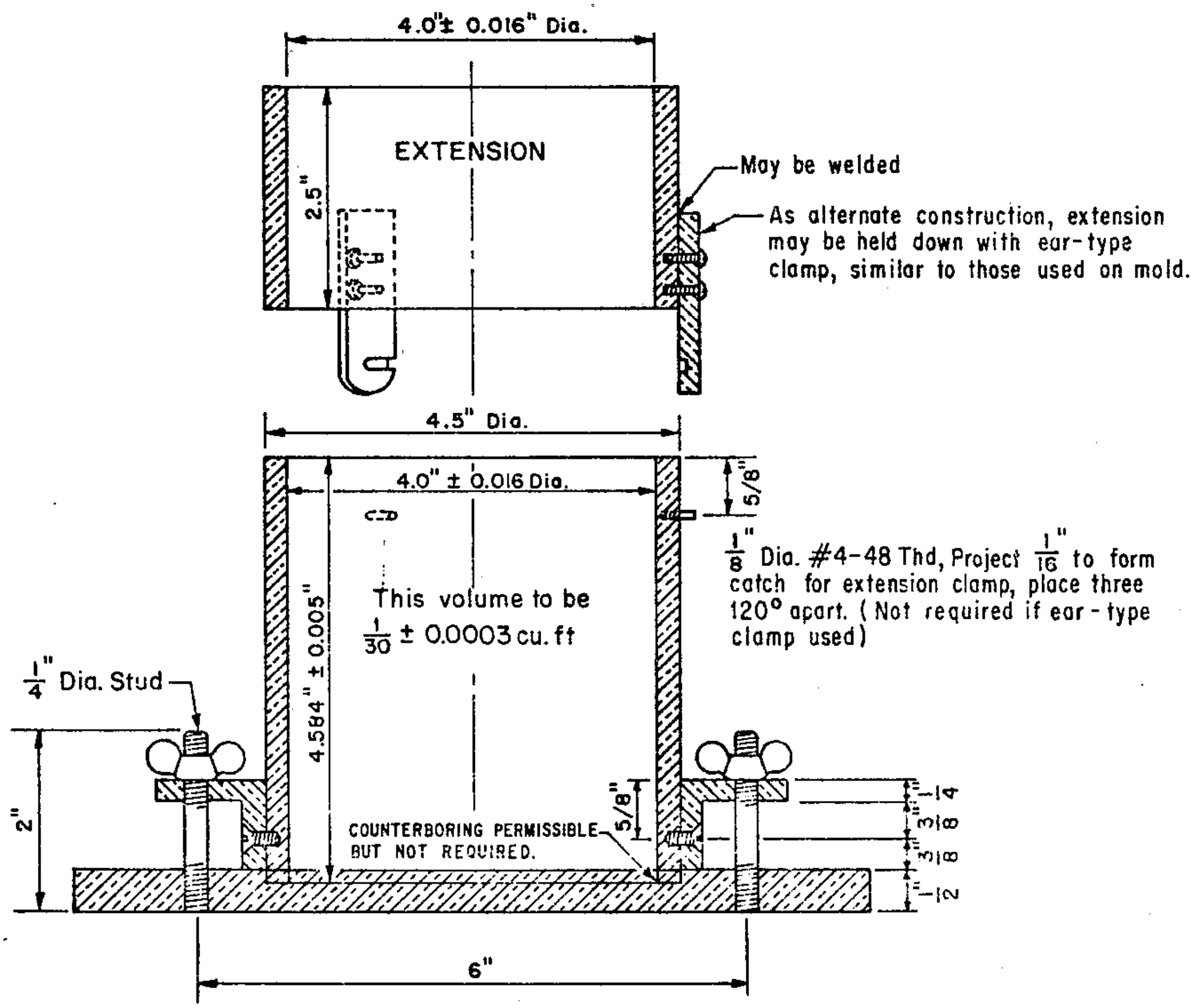

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1/16	1.59	3/4	19.05	4.500	114.30
1/8	3.18	2	50.80	4.584	116.43
1/4	6.35	2 1/2	63.50	6.000	152.40

cu. ft.	cu. cm.
1/30	944
0.0003	8

Fig. II STRAIGHTWALL MOLD

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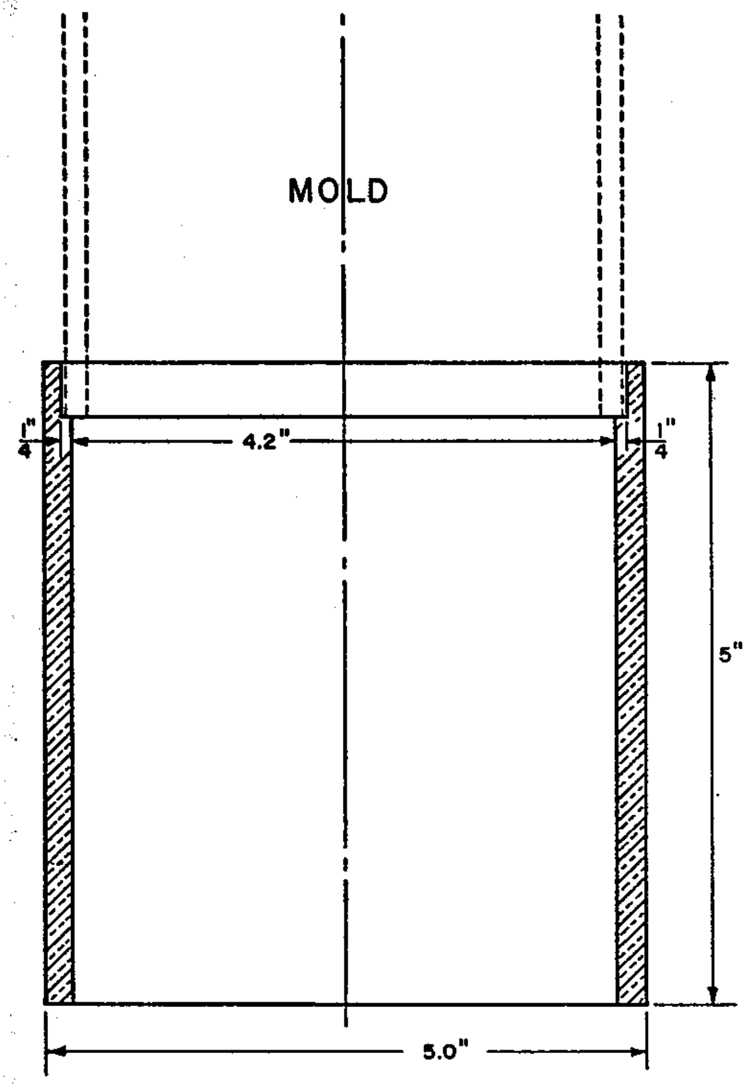

METRIC EQUIVALENTS					
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0.026	0.66	5/8	15.88	4.038	102.57
1/16	1.59	3/4	19.05	4.500	114.30
1/8	3.18	2	50.80	4.584	116.43
1/4	6.35	2 1/2	63.50	6.000	152.40

cu. ft.	cu. cm.
1/30	9.44
0.0003	8

Fig. III EXTRACTION DEVICE

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FIGURE IV

State of California — Department of Transportation

RELATIVE COMPACTION TEST

Stamp	
Contract	Test No.
Type of Material	
Material From	
Impact by	Sand Volume By
Date	Date
Remarks	

SAND VOLUME DATA

A	Initial Wt. Sand	
B	Wt. of Residue	
C	Wt. of Sand Used (A–B)	
D	Sand Density	
E	Vol. Hole + Cone (C/D)	
F	Vol. of Cone	
G	Vol. of Hole (E–F)	
H	Wet Den. gm/cc (L/G)	

IMPACT TEST DATA

I	Initial Wet Weight of Test Specimen (Grams)	2100			
	Increment	1	2	3	4
	Water Adjustment (grams)	0	+50	+100	
J	Final Core Wt. (grams)	2040	2124	2145	
K	Wet Density (gms/cc)	2.16	2.19	2.17	

K From Table 1 — Highest Density is Test Max

Percent Relative Compaction (H/K)	Spec	Failed	or less
		Passed	

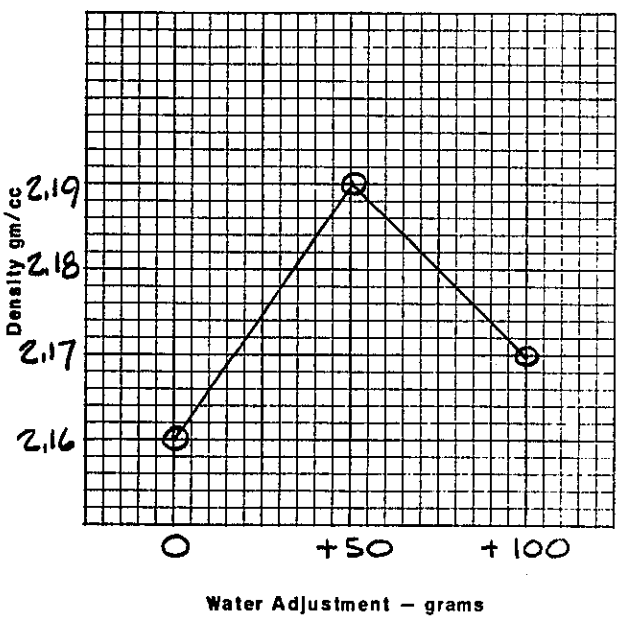
ROCK ADJUSTMENT CALCULATION *

		Grams	%
L	Total Sample Wt. (–2" Mat.)		
M	2" x ¾"		
N	¾ x #4		
O	Passing #4		

BATCH WEIGHT FOR INITIAL WEIGHT OF TEST SPECIMEN

P	¾ x #4 (M + N) x Init. Wt. (grams)	
Q	Pass #4 O x Init. Wt. (grams)	
R	Total Init. Wt. Record on L (grams)	

* Rock Adjustment Required If M ≥ 10%



MOISTURE ADJUSTMENT FOR AGGREGATE BASE PAY QUANTITY

a	In-place Wet Weight (grams)		e	Test Specimen Wet Wt. (Opt.) (grams)	
b	In-place Dry Weight (grams)		f	Test Specimen Dry Weight (grams)	
c	In-place Water (a–b) (grams)		g	Test Specimen Water (e–f) (grams)	
d	In-place % Water (c/b)		h	Test Specimen % Water (g/f)	

Moisture Correction (h + 1%) – d =

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FIGURE V

State of California

RELATIVE COMPACTION TEST–NUCLEAR

Department of Transportation

Job Stamp	Contract	Test No.
	Type of Material	
	Material From	
	Impact by	Nuclear by
	Date	Date
Show test location and area limits	Non Biased Plan No.	Gage No.

IN-PLACE TEST BY NUCLEAR

	Site	Den. Ct. ___" D.T.	Std. Count Density
A	1		
	2		
	3		Σ
	4		F X̄
	5		Moist Count 1
			2
	6		3
			4
	7		5
			6
	8		7
			8
B	Σ		Σ
C	X̄		G X̄
CR(C/F)			CR(G/I)
D	X̄ Den.gm/cc		H X̄H2O g/cc
E	X̄ Den. Corr. for Moist ** ±		

** E = D ± Difference Between X̄ H_2O From Common Test Maximum & H

If Com. Test Max. is Used X̄ K =

X̄ H2O =	Fr. Test	Dated

Percent Relative Compaction (E/K)		Spec.	Individual	
			Moving Av.	

Remarks:

IMPACT TEST DATA

J	Initial Wet Weight of Test Specimen (Grams)	2100			
	Specimen	1	2	3	4
	Water Adjustment	0	+50	+100	
	Final Core Wt. (grams)	2040	2124	2145	
K	Wet Density (gm/cc)	2.16	2.19	2.17	
	K From Table 1	Highest Density is Test Maximum			

	Rock Adjustment Calculations *	Grams	%
L	Total Sample Wt. (–2" Mat.)		
M	2"x ¾"		
N	¾"x #4		
O	Passing #4		

BATCH WEIGHT FOR INITIAL WEIGHT OF TEST SPECIMEN

P	¾ x #4 (M+ N) x Initial Weight (grams)	
Q	P #4 O x Initial Weight (grams)	
R	Total Initial Wt. (P + Q) Record on Line J (grams)	

* Rock Adjustment Required If M ≥ 10%

Std. Count Moist.
Σ
I X̄

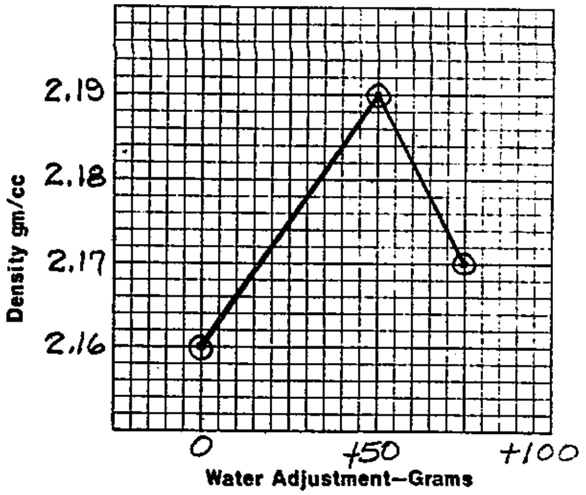

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TABLE 1 TM =WET TEST MAXIMUM DENSITY IN GM/CC FS/943.9B

EXAMPLE: F= 2040 GMS. S= 2050 GMS B= 2150 GMS. TM FROM TABLE= 2.06 GMS./CC

S	1600				
B	1500	1550	1600	1650	1700
S	1650				
B	1550	1600	1650	1700	1750
F	TM GMS/CC				
1250	1.41	1.37	1.32	1.28	1.25
1260	1.42	1.38	1.33	1.29	1.26
1270	1.44	1.39	1.35	1.30	1.27
1280	1.45	1.40	1.36	1.31	1.28
1290	1.46	1.41	1.37	1.33	1.29
1300	1.47	1.42	1.38	1.34	1.30
1310	1.48	1.43	1.39	1.35	1.31
1320	1.49	1.44	1.40	1.36	1.32
1330	1.50	1.45	1.41	1.37	1.33
1340	1.51	1.47	1.42	1.38	1.34
1350	1.53	1.48	1.43	1.39	1.35
1360	1.54	1.49	1.44	1.40	1.36
1370	1.55	1.50	1.45	1.41	1.37
1380	1.56	1.51	1.46	1.42	1.38
1390	1.57	1.52	1.47	1.43	1.39
1400	1.58	1.53	1.48	1.44	1.40
1410	1.59	1.54	1.49	1.45	1.41
1420	1.60	1.55	1.50	1.46	1.42
1430	1.62	1.56	1.51	1.47	1.43
1440	1.63	1.57	1.53	1.48	1.44
1450	1.64	1.59	1.54	1.49	1.45
1460	1.65	1.60	1.55	1.50	1.46
1470	1.66	1.61	1.56	1.51	1.47
1480	1.67	1.62	1.57	1.52	1.48
1490	1.68	1.63	1.58	1.53	1.49
1500	1.70	1.64	1.59	1.54	1.50
1510	1.71	1.65	1.60	1.55	1.51
1520	1.72	1.66	1.61	1.56	1.52
1530	1.73	1.67	1.62	1.57	1.53
1540	1.74	1.68	1.63	1.58	1.54
1550	1.75	1.70	1.64	1.59	1.55
1560	1.76	1.71	1.65	1.60	1.56
1570	1.77	1.72	1.66	1.61	1.57
1580	1.79	1.73	1.67	1.62	1.58
1590	1.80	1.74	1.68	1.63	1.59
1600	1.81	1.75	1.70	1.64	1.60
1610	1.82	1.76	1.71	1.65	1.61
1620	1.83	1.77	1.72	1.66	1.62
1630	1.84	1.78	1.73	1.67	1.63
1640	1.85	1.79	1.74	1.68	1.64
1650	1.86	1.80	1.75	1.70	1.65
1660	1.88	1.82	1.76	1.71	1.66
1670	1.89	1.83	1.77	1.72	1.67
1680	1.90	1.84	1.78	1.73	1.68
1690	1.91	1.85	1.79	1.74	1.69
1700	1.92	1.86	1.80	1.75	1.70
1710	1.93	1.87	1.81	1.76	1.71
1720	1.94	1.88	1.82	1.77	1.72
1730	1.96	1.89	1.83	1.78	1.73
1740	1.97	1.90	1.84	1.79	1.73
1750	1.98	1.91	1.85	1.80	1.74

S	1700				
B	1600	1650	1700	1750	1800
S	1750				
B	1650	1700	1750	1800	1850
F	TM GMS/CC				
1350	1.52	1.47	1.43	1.39	1.35
1360	1.53	1.48	1.44	1.40	1.36
1370	1.54	1.50	1.45	1.41	1.37
1380	1.55	1.51	1.46	1.42	1.38
1390	1.56	1.52	1.47	1.43	1.39
1400	1.58	1.53	1.48	1.44	1.40
1410	1.59	1.54	1.49	1.45	1.41
1420	1.60	1.55	1.50	1.46	1.42
1430	1.61	1.56	1.51	1.47	1.43
1440	1.62	1.57	1.53	1.48	1.44
1450	1.63	1.58	1.54	1.49	1.45
1460	1.64	1.59	1.55	1.50	1.46
1470	1.65	1.60	1.56	1.51	1.47
1480	1.67	1.62	1.57	1.52	1.48
1490	1.68	1.63	1.58	1.53	1.49
1500	1.69	1.64	1.59	1.54	1.50
1510	1.70	1.65	1.60	1.55	1.51
1520	1.71	1.66	1.61	1.56	1.52
1530	1.72	1.67	1.62	1.57	1.53
1540	1.73	1.68	1.63	1.58	1.54
1550	1.74	1.69	1.64	1.60	1.55
1560	1.76	1.70	1.65	1.61	1.56
1570	1.77	1.71	1.66	1.62	1.57
1580	1.78	1.72	1.67	1.63	1.58
1590	1.79	1.74	1.68	1.64	1.59
1600	1.80	1.75	1.70	1.65	1.60
1610	1.81	1.76	1.71	1.66	1.61
1620	1.82	1.77	1.72	1.67	1.62
1630	1.83	1.78	1.73	1.68	1.63
1640	1.85	1.79	1.74	1.69	1.64
1650	1.86	1.80	1.75	1.70	1.65
1660	1.87	1.81	1.76	1.71	1.66
1670	1.88	1.82	1.77	1.72	1.67
1680	1.89	1.83	1.78	1.73	1.68
1690	1.90	1.84	1.79	1.74	1.69
1700	1.91	1.86	1.80	1.75	1.70
1710	1.92	1.87	1.81	1.76	1.71
1720	1.94	1.88	1.82	1.77	1.72
1730	1.95	1.89	1.83	1.78	1.73
1740	1.96	1.90	1.84	1.79	1.74
1750	1.97	1.91	1.85	1.80	1.75
1760	1.98	1.92	1.86	1.81	1.76
1770	1.99	1.93	1.88	1.82	1.77
1780	2.00	1.94	1.89	1.83	1.78
1790	2.01	1.95	1.90	1.84	1.79
1800	2.03	1.96	1.91	1.85	1.80
1810	2.04	1.98	1.92	1.86	1.81
1820	2.05	1.99	1.93	1.87	1.82
1830	2.06	2.00	1.94	1.88	1.83
1840	2.07	2.01	1.95	1.89	1.84
1850	2.08	2.02	1.96	1.90	1.85

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TABLE 1 TM =WET TEST MAXIMUM DENSITY IN GM/CC FS/943.9B
EXAMPLE: F= 2040 GMS. S= 2050 GMS B= 2150 GMS. TM FROM TABLE= 2.06 GMS./CC

S	1800				
B	1700	1750	1800	1850	1900
S	1850				
B	1750	1800	1850	1900	1950
F	TM GMS/CC				
1450	1.63	1.58	1.54	1.49	1.46
1460	1.64	1.59	1.55	1.50	1.47
1470	1.65	1.60	1.56	1.52	1.48
1480	1.66	1.61	1.57	1.53	1.49
1490	1.67	1.62	1.58	1.54	1.50
1500	1.68	1.63	1.59	1.55	1.51
1510	1.69	1.65	1.60	1.56	1.52
1520	1.71	1.66	1.61	1.57	1.53
1530	1.72	1.67	1.62	1.58	1.54
1540	1.73	1.68	1.63	1.59	1.55
1550	1.74	1.69	1.64	1.60	1.56
1560	1.75	1.70	1.65	1.61	1.57
1570	1.76	1.71	1.66	1.62	1.58
1580	1.77	1.72	1.67	1.63	1.59
1590	1.78	1.73	1.68	1.64	1.60
1600	1.79	1.74	1.70	1.65	1.61
1610	1.81	1.75	1.71	1.66	1.62
1620	1.82	1.77	1.72	1.67	1.63
1630	1.83	1.78	1.73	1.68	1.64
1640	1.84	1.79	1.74	1.69	1.65
1650	1.85	1.80	1.75	1.70	1.66
1660	1.86	1.81	1.76	1.71	1.67
1670	1.87	1.82	1.77	1.72	1.68
1680	1.88	1.83	1.78	1.73	1.69
1690	1.90	1.84	1.79	1.74	1.70
1700	1.91	1.85	1.80	1.75	1.71
1710	1.92	1.86	1.81	1.76	1.72
1720	1.93	1.87	1.82	1.77	1.73
1730	1.94	1.89	1.83	1.78	1.74
1740	1.95	1.90	1.84	1.79	1.75
1750	1.96	1.91	1.85	1.80	1.76
1760	1.97	1.92	1.86	1.81	1.77
1770	1.99	1.93	1.88	1.82	1.78
1780	2.00	1.94	1.89	1.83	1.79
1790	2.01	1.95	1.90	1.85	1.80
1800	2.02	1.96	1.91	1.86	1.81
1810	2.03	1.97	1.92	1.87	1.82
1820	2.04	1.98	1.93	1.88	1.83
1830	2.05	1.99	1.94	1.89	1.84
1840	2.06	2.01	1.95	1.90	1.85
1850	2.08	2.02	1.96	1.91	1.86
1860	2.09	2.03	1.97	1.92	1.87
1870	2.10	2.04	1.98	1.93	1.88
1880	2.11	2.05	1.99	1.94	1.89
1890	2.12	2.06	2.00	1.95	1.90
1900	2.13	2.07	2.01	1.96	1.91
1910	2.14	2.08	2.02	1.97	1.92
1920	2.15	2.09	2.03	1.98	1.93
1930	2.16	2.10	2.04	1.99	1.94
1940	2.18	2.11	2.06	2.00	1.95
1950	2.19	2.12	2.07	2.01	1.96

S	1900				
B	1800	1850	1900	1950	2000
S	1950				
B	1850	1900	1950	2000	2050
F	TM GMS/CC				
1550	1.73	1.69	1.64	1.60	1.56
1560	1.74	1.70	1.65	1.61	1.57
1570	1.76	1.71	1.66	1.62	1.58
1580	1.77	1.72	1.67	1.63	1.59
1590	1.78	1.73	1.68	1.64	1.60
1600	1.79	1.74	1.70	1.65	1.61
1610	1.80	1.75	1.71	1.66	1.62
1620	1.81	1.76	1.72	1.67	1.63
1630	1.82	1.77	1.73	1.68	1.64
1640	1.83	1.78	1.74	1.69	1.65
1650	1.85	1.80	1.75	1.70	1.66
1660	1.86	1.81	1.76	1.71	1.67
1670	1.87	1.82	1.77	1.72	1.68
1680	1.88	1.83	1.78	1.73	1.69
1690	1.89	1.84	1.79	1.74	1.70
1700	1.90	1.85	1.80	1.75	1.71
1710	1.91	1.86	1.81	1.77	1.72
1720	1.92	1.87	1.82	1.78	1.73
1730	1.93	1.88	1.83	1.79	1.74
1740	1.95	1.89	1.84	1.80	1.75
1750	1.96	1.90	1.85	1.81	1.76
1760	1.97	1.91	1.86	1.82	1.77
1770	1.98	1.93	1.88	1.83	1.78
1780	1.99	1.94	1.89	1.84	1.79
1790	2.00	1.95	1.90	1.85	1.80
1800	2.01	1.96	1.91	1.86	1.81
1810	2.02	1.97	1.92	1.87	1.82
1820	2.04	1.98	1.93	1.88	1.83
1830	2.05	1.99	1.94	1.89	1.84
1840	2.06	2.00	1.95	1.90	1.85
1850	2.07	2.01	1.96	1.91	1.86
1860	2.08	2.02	1.97	1.92	1.87
1870	2.09	2.03	1.98	1.93	1.88
1880	2.10	2.05	1.99	1.94	1.89
1890	2.11	2.06	2.00	1.95	1.90
1900	2.12	2.07	2.01	1.96	1.91
1910	2.14	2.08	2.02	1.97	1.92
1920	2.15	2.09	2.03	1.98	1.93
1930	2.16	2.10	2.04	1.99	1.94
1940	2.17	2.11	2.06	2.00	1.95
1950	2.18	2.12	2.07	2.01	1.96
1960	2.19	2.13	2.08	2.02	1.97
1970	2.20	2.14	2.09	2.03	1.98
1980	2.21	2.15	2.10	2.04	1.99
1990	2.23	2.17	2.11	2.05	2.00
2000	2.24	2.18	2.12	2.06	2.01
2010	2.25	2.19	2.13	2.07	2.02
2020	2.26	2.20	2.14	2.09	2.03
2030	2.27	2.21	2.15	2.10	2.04
2040	2.28	2.22	2.16	2.11	2.05
2050	2.29	2.23	2.17	2.12	2.06

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TABLE 1 TM =WET TEST MAXIMUM DENSITY IN GM/CC FS/943.9B
EXAMPLE: F= 2040 GMS. S= 2050 GMS B= 2150 GMS. TM FROM TABLE= 2.06 GMS./CC

S	2000				
B	1900	1950	2000	2050	2100
S	2050				
B	1950	2000	2050	2100	2150
F	TM GMS/CC				
1650	1.84	1.79	1.75	1.71	1.66
1660	1.85	1.80	1.76	1.72	1.67
1670	1.86	1.81	1.77	1.73	1.69
1680	1.87	1.83	1.78	1.74	1.70
1690	1.88	1.84	1.79	1.75	1.71
1700	1.90	1.85	1.80	1.76	1.72
1710	1.91	1.86	1.81	1.77	1.73
1720	1.92	1.87	1.82	1.78	1.74
1730	1.93	1.88	1.83	1.79	1.75
1740	1.94	1.89	1.84	1.80	1.76
1750	1.95	1.90	1.85	1.81	1.77
1760	1.96	1.91	1.86	1.82	1.78
1770	1.97	1.92	1.88	1.83	1.79
1780	1.99	1.93	1.89	1.84	1.80
1790	2.00	1.95	1.90	1.85	1.81
1800	2.01	1.96	1.91	1.86	1.82
1810	2.02	1.97	1.92	1.87	1.83
1820	2.03	1.98	1.93	1.88	1.84
1830	2.04	1.99	1.94	1.89	1.85
1840	2.05	2.00	1.95	1.90	1.86
1850	2.06	2.01	1.96	1.91	1.87
1860	2.07	2.02	1.97	1.92	1.88
1870	2.09	2.03	1.98	1.93	1.89
1880	2.10	2.04	1.99	1.94	1.90
1890	2.11	2.05	2.00	1.95	1.91
1900	2.12	2.06	2.01	1.96	1.92
1910	2.13	2.08	2.02	1.97	1.93
1920	2.14	2.09	2.03	1.98	1.94
1930	2.15	2.10	2.04	1.99	1.95
1940	2.16	2.11	2.06	2.01	1.96
1950	2.17	2.12	2.07	2.02	1.97
1960	2.19	2.13	2.08	2.03	1.98
1970	2.20	2.14	2.09	2.04	1.99
1980	2.21	2.15	2.10	2.05	2.00
1990	2.22	2.16	2.11	2.06	2.01
2000	2.23	2.17	2.12	2.07	2.02
2010	2.24	2.18	2.13	2.08	2.03
2020	2.25	2.19	2.14	2.09	2.04
2030	2.26	2.21	2.15	2.10	2.05
2040	2.27	2.22	2.16	2.11	2.06
2050	2.29	2.23	2.17	2.12	2.07
2060	2.30	2.24	2.18	2.13	2.08
2070	2.31	2.25	2.19	2.14	2.09
2080	2.32	2.26	2.20	2.15	2.10
2090	2.33	2.27	2.21	2.16	2.11
2100	2.34	2.28	2.2[illegible]	2.17	2.12
2110	2.35	2.29	2.24	2.18	2.13
2120	2.36	2.30	2.25	2.19	2.14
2130	2.38	2.31	2.26	2.20	2.15
2140	2.39	2.33	2.27	2.21	2.16
2150	2.40	2.34	2.28	2.2[illegible]	2.17

S	2100				
B	2000	2050	2100	2150	2200
S	2150				
B	2050	2100	2150	2200	2250
F	TM GMS/CC				
1750	1.95	1.90	1.85	1.81	1.77
1760	1.96	1.91	1.86	1.82	1.78
1770	1.97	1.92	1.88	1.83	1.79
1780	1.98	1.93	1.89	1.84	1.80
1790	1.99	1.94	1.90	1.85	1.81
1800	2.00	1.95	1.91	1.86	1.82
1810	2.01	1.96	1.92	1.87	1.83
1820	2.02	1.98	1.93	1.88	1.84
1830	2.04	1.99	1.94	1.89	1.85
1840	2.05	2.00	1.95	1.90	1.86
1850	2.06	2.01	1.96	1.91	1.87
1860	2.07	2.02	1.97	1.92	1.88
1870	2.08	2.03	1.98	1.94	1.89
1880	2.09	2.04	1.99	1.95	1.90
1890	2.10	2.05	2.00	1.96	1.91
1900	2.11	2.06	2.01	1.97	1.92
1910	2.12	2.07	2.02	1.98	1.93
1920	2.14	2.08	2.03	1.99	1.94
1930	2.15	2.09	2.04	2.00	1.95
1940	2.16	2.11	2.06	2.01	1.96
1950	2.17	2.12	2.07	2.02	1.97
1960	2.18	2.13	2.08	2.03	1.98
1970	2.19	2.14	2.09	2.04	1.99
1980	2.20	2.15	2.10	2.05	2.00
1990	2.21	2.16	2.11	2.06	2.01
2000	2.22	2.17	2.12	2.07	2.02
2010	2.24	2.18	2.13	2.08	2.03
2020	2.25	2.19	2.14	2.09	2.04
2030	2.26	2.20	2.15	2.10	2.05
2040	2.27	2.21	2.16	2.11	2.06
2050	2.28	2.2[illegible]	2.17	2.12	2.07
2060	2.29	2.24	2.18	2.13	2.08
2070	2.30	2.25	2.19	2.14	2.09
2080	2.31	2.26	2.20	2.15	2.10
2090	2.32	2.27	2.21	2.16	2.11
2100	2.34	2.28	2.2[illegible]	2.17	2.12
2110	2.35	2.29	2.24	2.18	2.13
2120	2.36	2.30	2.25	2.19	2.14
2130	2.37	2.31	2.26	2.20	2.15
2140	2.38	2.32	2.27	2.21	2.16
2150	2.39	2.33	2.28	2.2[illegible]	2.17
2160	2.40	2.34	2.29	2.24	2.18
2170	2.41	2.36	2.30	2.25	2.19
2180	2.43	2.37	2.31	2.26	2.20
2190	2.44	2.38	2.32	2.27	2.21
2200	2.45	2.39	2.3[illegible]	2.28	2.2[illegible]
2210	2.46	2.40	2.34	2.29	2.23
2220	2.47	2.41	2.35	2.30	2.25
2230	2.48	2.42	2.36	2.31	2.26
2240	2.49	2.43	2.37	2.32	2.27
2250	2.50	2.44	2.38	2.3[illegible]	2.28

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TABLE 1   TM =WET TEST MAXIMUM DENSITY IN GM/CC   FS/943.9B

EXAMPLE: F= 2040 GMS. S= 2050 GMS B= 2150 GMS. TM FROM TABLE= 2.06 GMS./CC

S	2200				
B	2100	2150	2200	2250	2300
S	2250				
B	2150	2200	2250	2300	2350
F	TM GMS/CC				
1850	2.05	2.01	1.96	1.92	1.87
1860	2.06	2.02	1.97	1.93	1.88
1870	2.08	2.03	1.98	1.94	1.90
1880	2.09	2.04	1.99	1.95	1.91
1890	2.10	2.05	2.00	1.96	1.92
1900	2.11	2.06	2.01	1.97	1.93
1910	2.12	2.07	2.02	1.98	1.94
1920	2.13	2.08	2.03	1.99	1.95
1930	2.14	2.09	2.04	2.00	1.96
1940	2.15	2.10	2.06	2.01	1.97
1950	2.16	2.11	2.07	2.02	1.98
1960	2.18	2.12	2.08	2.03	1.99
1970	2.19	2.14	2.09	2.04	2.00
1980	2.20	2.15	2.10	2.05	2.01
1990	2.21	2.16	2.11	2.06	2.02
2000	2.22	2.17	2.12	2.07	2.03
2010	2.23	2.18	2.13	2.08	2.04
2020	2.24	2.19	2.14	2.09	2.05
2030	2.25	2.20	2.15	2.10	2.06
2040	2.26	2.21	2.16	2.11	2.07
2050	2.28	2.22	2.17	2.12	2.08
2060	2.29	2.23	2.18	2.13	2.09
2070	2.30	2.24	2.19	2.14	2.10
2080	2.31	2.25	2.20	2.15	2.11
2090	2.32	2.27	2.21	2.17	2.12
2100	2.33	2.28	2.22	2.18	2.13
2110	2.34	2.29	2.24	2.19	2.14
2120	2.35	2.30	2.25	2.20	2.15
2130	2.36	2.31	2.26	2.21	2.16
2140	2.38	2.32	2.27	2.22	2.17
2150	2.39	2.33	2.28	2.23	2.18
2160	2.40	2.34	2.29	2.24	2.19
2170	2.41	2.35	2.30	2.25	2.20
2180	2.42	2.36	2.31	2.26	2.21
2190	2.43	2.37	2.32	2.27	2.22
2200	2.44	2.38	2.33	2.28	2.23
2210	2.45	2.40	2.34	2.29	2.24
2220	2.46	2.41	2.35	2.30	2.25
2230	2.48	2.42	2.36	2.31	2.26
2240	2.49	2.43	2.37	2.32	2.27
2250	2.50	2.44	2.38	2.33	2.28
2260	2.51	2.45	2.39	2.34	2.29
2270	2.52	2.46	2.40	2.35	2.30
2280	2.53	2.47	2.42	2.36	2.31
2290	2.54	2.48	2.43	2.37	2.32
2300	2.55	2.49	2.44	2.38	2.33
2310	2.56	2.50	2.45	2.39	2.34
2320	2.57	2.52	2.46	2.40	2.35
2330	2.59	2.53	2.47	2.41	2.36
2340	2.60	2.54	2.48	2.42	2.37
2350	2.61	2.55	2.49	2.43	2.38

S	2300				
B	2200	2250	2300	2350	2400
S	2350				
B	2250	2300	2350	2400	2450
F	TM GMS/CC				
1950	2.16	2.11	2.07	2.02	1.98
1960	2.17	2.12	2.08	2.03	1.99
1970	2.18	2.13	2.09	2.04	2.00
1980	2.19	2.14	2.10	2.05	2.01
1990	2.20	2.16	2.11	2.06	2.02
2000	2.22	2.17	2.12	2.07	2.03
2010	2.23	2.18	2.13	2.08	2.04
2020	2.24	2.19	2.14	2.09	2.05
2030	2.25	2.20	2.15	2.10	2.06
2040	2.26	2.21	2.16	2.12	2.07
2050	2.27	2.22	2.17	2.13	2.08
2060	2.28	2.23	2.18	2.14	2.09
2070	2.29	2.24	2.19	2.15	2.10
2080	2.30	2.25	2.20	2.16	2.11
2090	2.31	2.26	2.21	2.17	2.12
2100	2.33	2.27	2.22	2.18	2.13
2110	2.34	2.29	2.24	2.19	2.14
2120	2.35	2.30	2.25	2.20	2.15
2130	2.36	2.31	2.26	2.21	2.16
2140	2.37	2.32	2.27	2.22	2.17
2150	2.38	2.33	2.28	2.23	2.18
2160	2.39	2.34	2.29	2.24	2.19
2170	2.40	2.35	2.30	2.25	2.20
2180	2.41	2.36	2.31	2.26	2.21
2190	2.43	2.37	2.32	2.27	2.22
2200	2.44	2.38	2.33	2.28	2.23
2210	2.45	2.39	2.34	2.29	2.24
2220	2.46	2.40	2.35	2.30	2.25
2230	2.47	2.42	2.36	2.31	2.26
2240	2.48	2.43	2.37	2.32	2.27
2250	2.49	2.44	2.38	2.33	2.28
2260	2.50	2.45	2.39	2.34	2.29
2270	2.51	2.46	2.40	2.35	2.30
2280	2.53	2.47	2.42	2.36	2.31
2290	2.54	2.48	2.43	2.37	2.33
2300	2.55	2.49	2.44	2.38	2.34
2310	2.56	2.50	2.45	2.40	2.35
2320	2.57	2.51	2.46	2.41	2.36
2330	2.58	2.52	2.47	2.42	2.37
2340	2.59	2.53	2.48	2.43	2.38
2350	2.60	2.54	2.49	2.44	2.39
2360	2.61	2.56	2.50	2.45	2.40
2370	2.62	2.57	2.51	2.46	2.41
2380	2.64	2.58	2.52	2.47	2.42
2390	2.65	2.59	2.53	2.48	2.43
2400	2.66	2.60	2.54	2.49	2.44
2410	2.67	2.61	2.55	2.50	2.45
2420	2.68	2.62	2.56	2.51	2.46
2430	2.69	2.63	2.57	2.52	2.47
2440	2.70	2.64	2.59	2.53	2.48
2450	2.71	2.65	2.60	2.54	2.49

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TABLE 1   TM =WET TEST MAXIMUM DENSITY IN GM/CC   FS/943.9B

EXAMPLE: F= 2040 GMS. S= 2050 GMS B= 2150 GMS. TM FROM TABLE= 2.06 GMS./CC

S	2400				
B	2300	2350	2400	2450	2500
S	2450				
B	2350	2400	2450	2500	2550
F	TM GMS/CC				
2050	2.27	2.22	2.17	2.13	2.08
2060	2.28	2.23	2.18	2.14	2.10
2070	2.29	2.24	2.19	2.15	2.11
2080	2.30	2.25	2.20	2.16	2.12
2090	2.31	2.26	2.21	2.17	2.13
2100	2.32	2.27	2.22	2.18	2.14
2110	2.33	2.28	2.24	2.19	2.15
2120	2.34	2.29	2.25	2.20	2.16
2130	2.35	2.30	2.26	2.21	2.17
2140	2.37	2.32	2.27	2.22	2.18
2150	2.38	2.33	2.28	2.23	2.19
2160	2.39	2.34	2.29	2.24	2.20
2170	2.40	2.35	2.30	2.25	2.21
2180	2.41	2.36	2.31	2.26	2.22
2190	2.42	2.37	2.32	2.27	2.23
2200	2.43	2.38	2.33	2.28	2.24
2210	2.44	2.39	2.34	2.29	2.25
2220	2.45	2.40	2.35	2.30	2.26
2230	2.47	2.41	2.36	2.31	2.27
2240	2.48	2.42	2.37	2.32	2.28
2250	2.49	2.43	2.38	2.34	2.29
2260	2.50	2.45	2.39	2.35	2.30
2270	2.51	2.46	2.40	2.36	2.31
2280	2.52	2.47	2.42	2.37	2.32
2290	2.53	2.48	2.43	2.38	2.33
2300	2.54	2.49	2.44	2.39	2.34
2310	2.55	2.50	2.45	2.40	2.35
2320	2.56	2.51	2.46	2.41	2.36
2330	2.58	2.52	2.47	2.42	2.37
2340	2.59	2.53	2.48	2.43	2.38
2350	2.60	2.54	2.49	2.44	2.39
2360	2.61	2.55	2.50	2.45	2.40
2370	2.62	2.56	2.51	2.46	2.41
2380	2.63	2.58	2.52	2.47	2.42
2390	2.64	2.59	2.53	2.48	2.43
2400	2.65	2.60	2.54	2.49	2.44
2410	2.66	2.61	2.55	2.50	2.45
2420	2.68	2.62	2.56	2.51	2.46
2430	2.69	2.63	2.57	2.52	2.47
2440	2.70	2.64	2.59	2.53	2.48
2450	2.71	2.65	2.60	2.54	2.49
2460	2.72	2.66	2.61	2.55	2.50
2470	2.73	2.67	2.62	2.56	2.51
2480	2.74	2.68	2.63	2.57	2.52
2490	2.75	2.69	2.64	2.58	2.53
2500	2.76	2.70	2.65	2.59	2.54
2510	2.77	2.72	2.66	2.60	2.55
2520	2.79	2.73	2.67	2.62	2.56
2530	2.80	2.74	2.68	2.63	2.57
2540	2.81	2.75	2.69	2.64	2.58
2550	2.82	2.76	2.70	2.65	2.59

S	2500				
B	2400	2450	2500	2550	2600
S	2550				
B	2450	2500	2550	2600	2650
F	TM GMS/CC				
2150	2.37	2.32	2.28	2.23	2.19
2160	2.38	2.34	2.29	2.24	2.20
2170	2.39	2.35	2.30	2.25	2.21
2180	2.41	2.36	2.31	2.26	2.22
2190	2.42	2.37	2.32	2.27	2.23
2200	2.43	2.38	2.33	2.29	2.24
2210	2.44	2.39	2.34	2.30	2.25
2220	2.45	2.40	2.35	2.31	2.26
2230	2.46	2.41	2.36	2.32	2.27
2240	2.47	2.42	2.37	2.33	2.28
2250	2.48	2.43	2.38	2.34	2.29
2260	2.49	2.44	2.39	2.35	2.30
2270	2.51	2.45	2.40	2.36	2.31
2280	2.52	2.46	2.42	2.37	2.32
2290	2.53	2.48	2.43	2.38	2.33
2300	2.54	2.49	2.44	2.39	2.34
2310	2.55	2.50	2.45	2.40	2.35
2320	2.56	2.51	2.46	2.41	2.36
2330	2.57	2.52	2.47	2.42	2.37
2340	2.58	2.53	2.48	2.43	2.38
2350	2.59	2.54	2.49	2.44	2.39
2360	2.60	2.55	2.50	2.45	2.40
2370	2.62	2.56	2.51	2.46	2.41
2380	2.63	2.57	2.52	2.47	2.42
2390	2.64	2.58	2.53	2.48	2.43
2400	2.65	2.59	2.54	2.49	2.44
2410	2.66	2.61	2.55	2.50	2.46
2420	2.67	2.62	2.56	2.51	2.47
2430	2.68	2.63	2.57	2.52	2.48
2440	2.69	2.64	2.59	2.53	2.49
2450	2.70	2.65	2.60	2.54	2.50
2460	2.71	2.66	2.61	2.56	2.51
2470	2.73	2.67	2.62	2.57	2.52
2480	2.74	2.68	2.63	2.58	2.53
2490	2.75	2.69	2.64	2.59	2.54
2500	2.76	2.70	2.65	2.60	2.55
2510	2.77	2.71	2.66	2.61	2.56
2520	2.78	2.72	2.67	2.62	2.57
2530	2.79	2.74	2.68	2.63	2.58
2540	2.80	2.75	2.69	2.64	2.59
2550	2.81	2.76	2.70	2.65	2.60
2560	2.83	2.77	2.71	2.66	2.61
2570	2.84	2.78	2.72	2.67	2.62
2580	2.85	2.79	2.73	2.68	2.63
2590	2.86	2.80	2.74	2.69	2.64
2600	2.87	2.81	2.75	2.70	2.65
2610	2.88	2.82	2.77	2.71	2.66
2620	2.89	2.83	2.78	2.72	2.67
2630	2.90	2.84	2.79	2.73	2.68
2640	2.91	2.85	2.80	2.74	2.69
2650	2.92	2.86	2.81	2.75	2.70

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APPENDIX C, Part 2

SUMMARY OF DIFFERENCES BETWEEN A.S.T.M. 1557-70 AND PROPOSED CALIFORNIA MODIFIED 1557 TEST METHODS

Test Apparatus and Compaction Procedure

With regard to apparatus, the two test methods have generally identical requirements. However, A.S.T.M. 1557 allows the option of either a round or a sector face of equal area for use as the mechanical rammer. The California method specified the round face for both manual and mechanical rammers.

Obtaining the Bulk Sample

The A.S.T.M. 1557 test method does not require a specific procedure for obtaining the bulk sample.

The proposed California modified 1557 test procedure for obtaining the bulk sample is determined by the type of in-place density test method specified. These density sampling procedures are as follows:

For Test Method No. Calif. 216 (sand volume) a bulk sample weighing 20 to 25 pounds shall be obtained from the site of the in-place density test hole.

For Test Method No. Calif. 231 (Nuclear Gage Area Concept) equal and representative portions of material from each nuclear test site within the area being tested shall be obtained and thoroughly mixed together to form a composite sample.

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Both the sand volume and the nuclear test method state the importance of maintaining the in-place moisture content unchanged until the test procedure has been completed.

Bulk Sample Preparation

The A.S.T.M. 1557 test method has four alternate test procedures and two methods specified for sample preparation depending on the soil particle size..

Methods A and B state that if the soil is damp, it should be dried until friable and passed through a No. 4 sieve. Coarse material retained on the No. 4 sieve is discarded.

Methods C and D specify the same procedure as Methods A and B except that the material is passed through a 3/4-inch sieve and the retained 3/4-inch material is discarded.

The proposed California modified 1557 method discards any rock retained on a 2-inch sieve. The material passing the 2-inch sieve is then passed through a 3/4-inch sieve. The percentage of material retained on the 3/4-inch sieve is then computed. It is of utmost importance that moisture loss be kept to a minimum.

Test Procedure

The A.S.T.M. 1557 method has four alternate procedures depending on soil particle size.

Method A is specified for material passing the No. 4 sieve and uses a four inch diameter mold.

Method B is the same as Method A but specifies a six inch diameter mold.

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Method C is specified for material passing a 3/4-inch sieve and uses a four inch diameter mold. It states that if it is advisable to maintain the same percentage of coarse material (passing a 2-inch sieve and retained on a No. 4 sieve), the passing 2-inch sieve and retained on the 3/4-inch sieve material shall be replaced with an equal weight of material passing the 3/4-inch sieve and retained on the No. 4 sieve.

Method D is the same as Method C but specified a six inch diameter mold.

The method to be used should be indicated in the specification for the material being tested. If no method is specified, the provisions of Method A govern.

The proposed California modified 1557 involves two procedural alternatives, dependent on soil particle size.

The first procedure is for material with less than 10% retained 3/4-inch rock. The retained 3/4-inch material is discarded and the passing 3/4-inch material is compacted into the 4-inch diameter mold.

The second procedure is for material having 10% or more 3/4-inch rock. The same procedure is used as the A.S.T.M. 1557 test method (Methods C and D) which replaces the passing 2-inch sieve and retained 3/4-inch sieve material with an equal weight of material passing the 3/4-inch sieve and retained on the No. 4 sieve. The proposed method makes this coarse rock substitution mandatory whereas the A.S.T.M. 1557-70 makes this rock substitution advisable. This portion of the A.S.T.M. is therefore questionable to proper application.

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When the proposed California modified 1557 test method is adopted, a 6-inch diameter mold will be specified for the second procedure.

Moisture-Density Relationships

The A.S.T.M. 1557 test method specifies oven drying of each compacted specimen to determine the moisture content. The dry unit weights of the soils in pounds per cubic foot are plotted as ordinates, and the corresponding moisture contents as abscissas. A smooth curve is drawn through the points and the peak of the curve represents the maximum dry density at optimum moisture content.

The proposed California modified 1557 test method adds water to, or subtracts it from, two or more test specimens having the identical weight of a trial specimen which is compacted at the in-place moisture content. The wet unit weights in grams per cubic centimeter are plotted as ordinates and the corresponding grams of water added to, or subtracted from, the specimen as abscissas. A curve is then drawn by connecting the points with a series of straight lines. The density at the peak of the curve is the maximum wet density. If the actual moisture content is needed, the maximum density specimen can be oven dried.

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APPENDIX D

SUMMARY OF DISTRICT RESPONSES TO QUESTIONNAIRE

A copy of the modified ASTM 1557 test method (Appendix C), developed at the completion of this study, was sent to each California Department of Transportation District for their review and comments. Unsolicited comments were received from several City and County Public Works Departments and from one private soil testing laboratory in the San Francisco Bay area.

Response to the questionnaire ranged from positive to very negative reactions to the proposed changeover from the present Test Method No. Calif. 216 to a modified version of Test Method ASTM 1557. A summation of these responses is listed below:

Responses in favor of the changeover

1. The California Department of Transportation would be equipped to perform the standard ASTM 1557 when requested by other agencies, since the same test apparatus is used for both the proposed modified and the standard ASTM 1557 procedures.

2. The modified ASTM 1557 method would give California a test method that would comply more closely to the universally accepted ASTM 1557 than does the present T. M. No. Calif. 216.

3. The elimination of the specific gravity for materials with 10 percent or more 3/4-inch rock will permit faster results.

4. The constant volume, variable weight method is a vast improvement over the current variable volume constant weight method.

5. The modified 1557 test procedure should help to eliminate some of the confusion now associated with the wet method used in the present T. M. No. Calif. 216 method.

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6. The rock correction procedure for the modified 1557 is faster than that used for the T. M. No. Calif. 216.

7. The automatic mechanical compactor will be an excellent method to certify compaction testers.

Reponses against the changeover

1. An unfavorable financial climate combined with manpower reductions would make any changeover at this time impractical.

2. The modified ASTM 1557 test method would be more time consuming and would not increase test accuracy.

3. The required wet screening of 3/4-inch by No. 4 clay material is an impossibility for replacing the oversized material as part of the rock correction procedure.

4. Trimming the compacted sample when testing rocky material is a problem.

5. At the present time only a few governmental agencies in California utilize the ASTM 1557 test method.

6. Test Method No. Calif. 216 is more versatile, efficient, and generally more satisfactory than ASTM 1557. (This response was from a private soil testing laboratory in the San Francisco Bay Area that uses both test methods.)

7. Considering the added cost, the fact that the test takes longer to run and would require re-training and re-certification on a statewide basis, there would be insufficient advantage gain to warrant changing from the present test method to ASTM test method at this time.

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8. The ASTM 1557 test method is a much slower procedure than T. M. No. Calif. 216.

9. One county implied that if California changed test methods, they would continue with T. M. No. Calif. 216.

A meeting was held with representatives from the Office of Construction and the Transportation Laboratory to discuss these responses and the possible change in test method for maximum density. It was decided to retain Test Method No. Calif. 216 for the present. This decision was based upon the Caltrans financial situation, the loss of qualified testing personnel, and the fact that the CTB maximum density would not be included in the modified test method until additional research data is available.

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